MACHINE TOOLS AT WORK

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Applications of Modern Machine Tools of Various Types Illustrated by Selected Examples from Actual Practice in Many Different Shops, Accompanied by Close-up Action Photographs and Condensed Descriptions Including Outstanding Features of Each Job, with Speed, Feed, and Other Practical Shop Data

By

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Machine Tools at Work

The purpose of this book is to present condensed illustrated descriptions of the more unusual operations on many different types of modern machine tools. These illustrations, with the accompanying descriptive matter and operating data, are intended chiefly for those who have at least a fair knowledge of machine shop practice. These operations have been selected because they represent approved practice and illustrate many unusual applications of the latest designs and types of machine tools.

This book is not intended as a complete pictorial treatise covering every kind of operation and every make of machine tool, because this plan would necessarily embrace many commonplace operations of little or no educational value to the general group likely to use this book as a source of information. The 430 illustrated descriptions are intended more especially for advanced or graduate apprentices, machinists, and also for shop executives interested in the equipment and procedure employed in many different types of machine-building plants. These plants are manufacturing products requiring precise, efficient methods. The work ranges from small light parts to machining of very heavy castings and forgings; consequently, the machine tools illustrated represent not only many different types, but a wide range of sizes. These illustrations were secured from many of the most progressive plants in the United States. Such exacting operations as are found in the manufacture of airplane engines, ordnance, etc., are included because they represent exceptionally high development in machine shop practice.

Careful reading of these illustrated descriptions will enable anyone understanding the elementary principles of shop practice, to acquire a broad knowledge of the most

advanced methods. The illustrations in all cases show actual examples obtained right from the manufacturing plant and include many special and unusual jobs. Operations have been selected which show the practical application of those methods and principles which have proved successful. While this book illustrates the machining of actual machine parts of many kinds, the primary purpose is to show the application of fundamental principles which may be utilized in any kind of production where there is a similar manufacturing problem.

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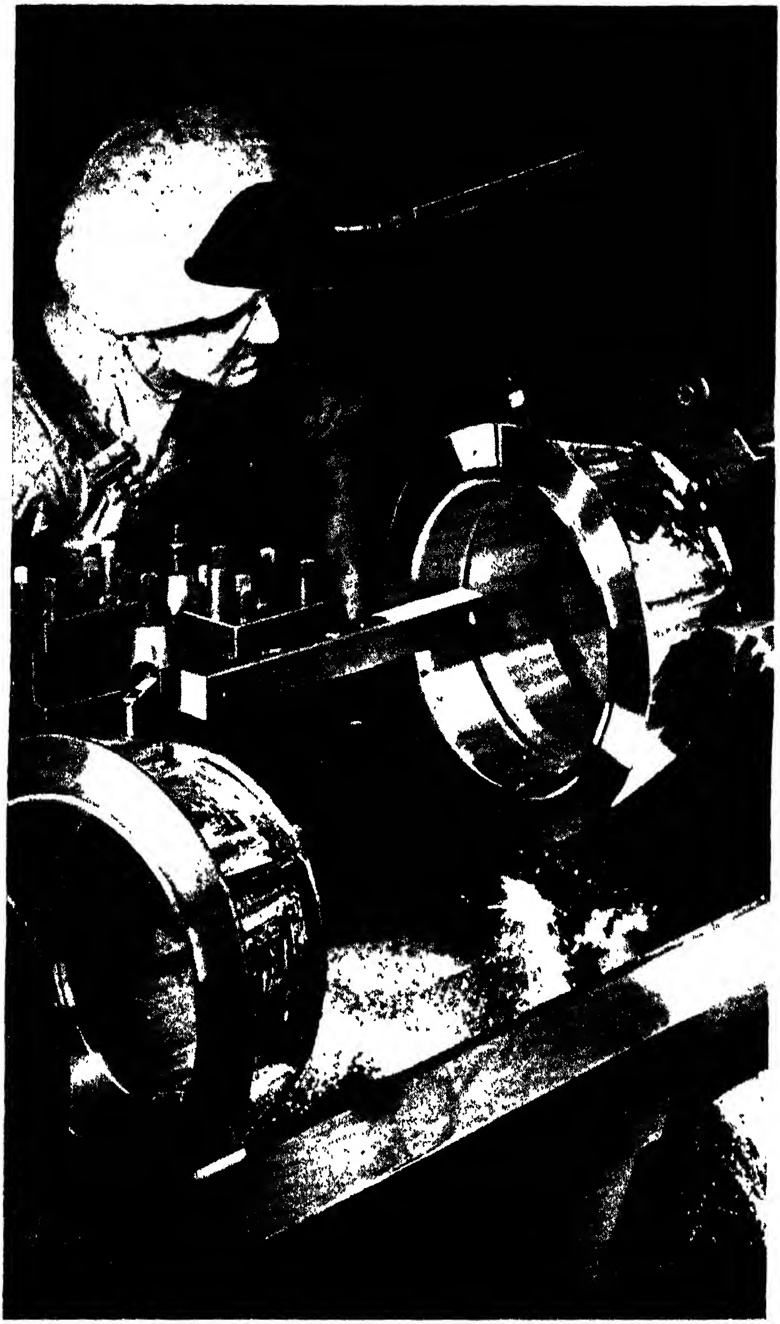

Operations on Machine Tools of the Lathe Type

Machine tools belonging to the lathe family comprise several distinct types. One type, commonly referred to as an "engine lathe" or simply as a "lathe," might be defined as a general-purpose machine because it is intended for application to various turning operations, especially when the number of duplicate parts is limited and a more special type of lathe is not required to obtain a higher rate of production. Some miscellaneous operations on ordinary lathes will precede the applications of the more special designs of lathes which are commonly used in manufacturing duplicate parts. The great advantage of the ordinary lathe for work within its productive capacity is that simple inexpensive tools are used and a very large variety of turning, boring, facing, thread-cutting and other operations are possible.

Turning Strut of Landing Gear.—One of the first operations on the main strut of an airplane landing gear consists of rough-turning it on a lathe equipped as illustrated in Fig. 1, after which it is finish-turned on the same machine. In both operations, the cutter is fed along the desired path on the part through the use of a profile bar or cam mounted at the rear of the machine as shown.

Tungsten-carbide tools are used in rough- and finish-turning this chromium-molybdenum part, which was swaged from seamless-steel tubing. In rough-turning, the work is rotated at 241 R.P.M., which gives a surface speed of 330 feet a minute at the maximum diameter. The depth

of cut is about 3/16 inch, and the feed 0.015 inch per revolution. In finish-turning, the work is rotated at 320 R.P.M., which is equivalent to a surface speed of 440 feet per minute at the maximum diameter, and the depth of cut is 1/32 inch, the rate of feed again being 0.015 inch. The tailstock end of the work is supported on a large ball-bearing cone, which is mounted on a live center.

Cutting Screw Thread on Long Tube Requiring Internal Support.—The operation shown in Fig. 2 is that of cutting a thread on tubes 67 inches long by 1.218 inches outside diameter. These tubes are float retracting screws on flying

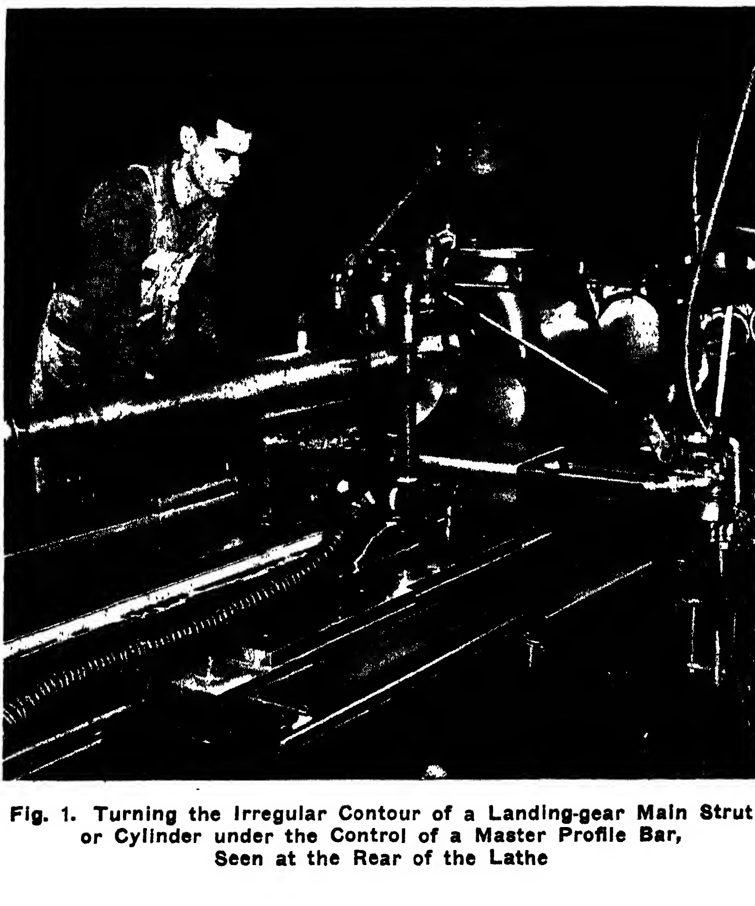

Fig. 1. Turning the Irregular Contour of a Landing-gear Main Strut or Cylinder under the Control of a Master Profile Bar, Seen at the Rear of the Lathe

boats. The inside diameter of the tube is 0.875 inch, leaving a wall thickness of only 0.1715 inch. The Acme double-lead thread must be true as to pitch diameter within plus 0.002 inch, minus 0, while the root diameter must be 1.038 inch, plus 0, minus 0.002 inch, as closely as can be checked with a depth micrometer. The outside diameter is held to plus 0.001 inch, minus 0.0005 inch. The tubing is of stainless steel.

Before each tube is brought to the lathe in which the operation is performed, a rod 11/16 inch in diameter is

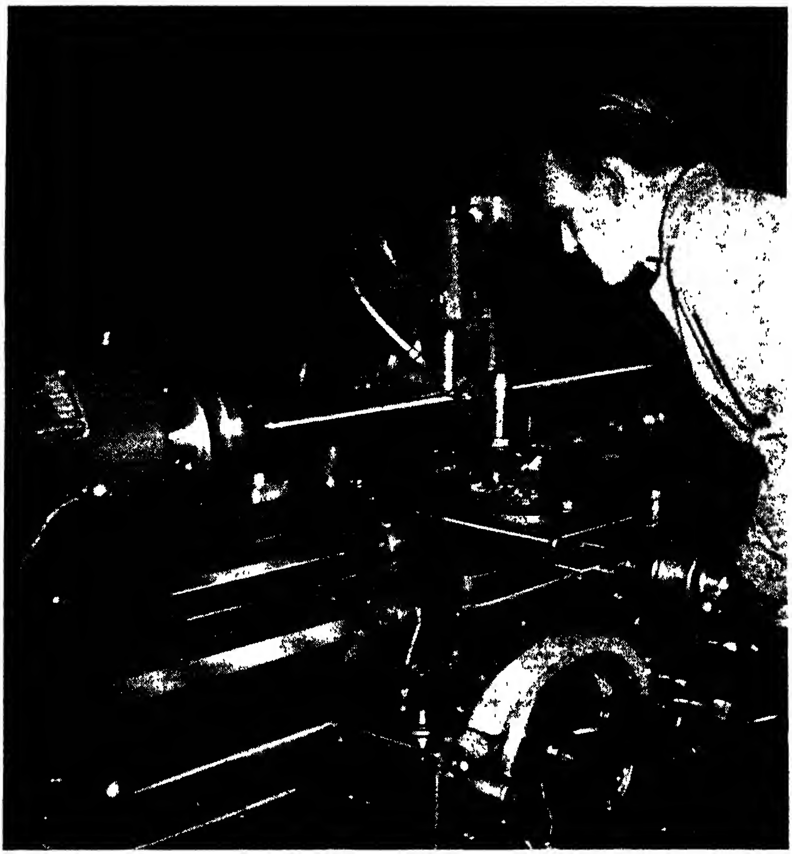

Fig. 2. Chasing Accurate Thread on a Long Tube that has been Filled with a Rod and Cerrobend to Provide Rigidity

Fig. 3. Turning a Propeller Shaft for a Battleship in a Lathe that has a Maximum Length Capacity of 55 Feet

inserted in the tube for approximately the full length, and the space between this rod and the inside of the tube is filled with molten Cerrobend to obtain, in effect, a solid bar. Plug centers are pressed into each end of the tube to facilitate holding it in the lathe. Rough cuts are taken on the screw thread until it has been cut within 0.025 inch of its final depth and within 1/16 inch of the specified pitch diameter. From thirty to forty cuts are taken in this roughing operation.

The screw is then centerless-ground to obtain the proper outside diameter within the tolerance mentioned, after which it is returned to the lathe for the finishing cuts. From fifty to sixty cuts are taken in finishing. The large number of cuts taken in roughing and finishing are necessary because of the tendency of the metal to stretch under heavy cuts. Finishing cuts are taken at about 35 surface feet per minute. In both roughing and finishing, a spring-neck tool-holder is used, and the screw is supported opposite the cutter by means of Micarta blocks, mounted on a follow-rest. This eliminates chatter when the cutter is operating near the middle of the long tube.

When the tube leaves the thread-chasing lathe, it must run true for its full length within 0.005 inch. This necessitates at least seven straightening operations, the first before the tube is placed in the engine lathe, and the others between threading cuts. Straightening is performed on a 20-ton hydraulic press.

Turning a Large Propeller Shaft.—Propeller shafts are machined in the engine lathe shown in Fig. 3, which has a swing of 64 inches and accommodates lengths up to 55 feet between centers. The operation shown consists of turning a shaft for a battleship, the weight of the shaft being approximately 24 tons, although some propeller shafts weigh as much as 33 tons. The shaft is hollow, having a hole of about 14 inches in diameter extending the full length. Some of the surfaces must be machined to close tolerances, as, for example, the tapered section to which the propeller is fitted, the diameter of which must be true within a tolerance of 0.0015 inch. The lathe is provided

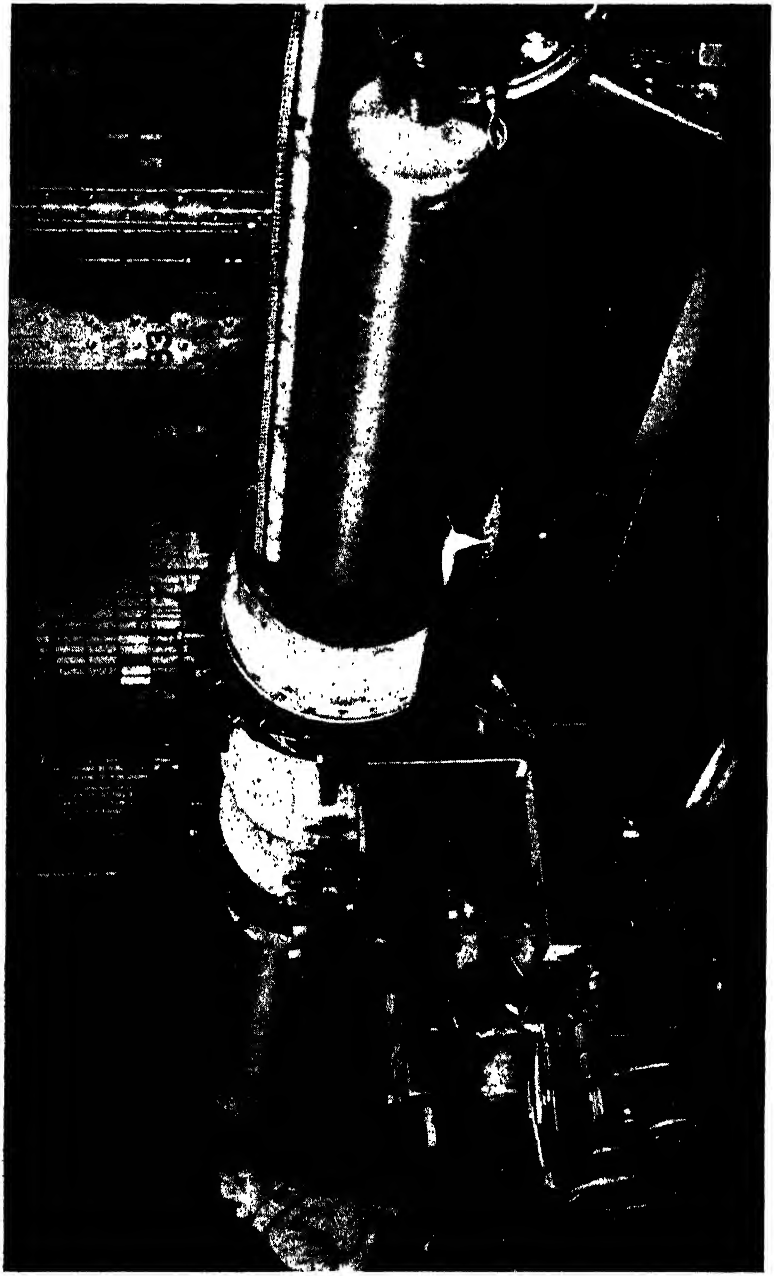

Fig. 4. Boring a Section for a Torpedo Tube on a Large Lathe

with two carriages, both of which are generally in use, so that one end of the long shaft can be turned while cuts are being taken on the opposite end.

Boring Torpedo Tube Section.—In Fig. 4 is shown a boring operation on the muzzle section of a 21-inch torpedo tube. It consists in boring the cylindrical seats at the ends and raised bearing surfaces that run lengthwise through the bronze castings. This section of the torpedo tube is approximately 6 feet 8 inches long; some sections are as long as 9 feet.

The torpedo-tube section is mounted on the lathe carriage and fed along the boring-bar for the operation. The boring-bar is of two diameters—about 18 inches for half its length and 12 inches for the remaining half. A cutter-head is attached to the shoulder where the large-diameter surface joins the smaller. In roughing, twelve radially positioned cutter bits are applied simultaneously. For finishing, two cutter-bits located diametrically opposite each other are used. Oil is fed directly to the cutters through the flexible hose seen extending into the torpedo tube.

Electrical Attachment for Turning Irregular Contours.—Metering pins, such as seen in the foreground in Fig. 5, must be machined to an irregularly changing contour, the diameters of which are held to specified dimensions within plus or minus 0.0005 inch. In the case of the metering pin shown between the centers of the lathe illustrated, there are four different straight diameters connected by tapered sections. The diameters range between 0.383 and 0.490 inch, the over-all length of the metering pin being 7 1/2 inches.

The desired contour of the metering pins is obtained by means of the Keller attachment at the rear of the machine, a tracer following along a master made to the same contour. The in-and-out movements of the tracer as it follows the master are imparted by electrical means to the tool-slide, so that the tool moves in and out in similar fashion. Roughing and finishing cuts are taken, after which the metering pin is polished in the same lathe.

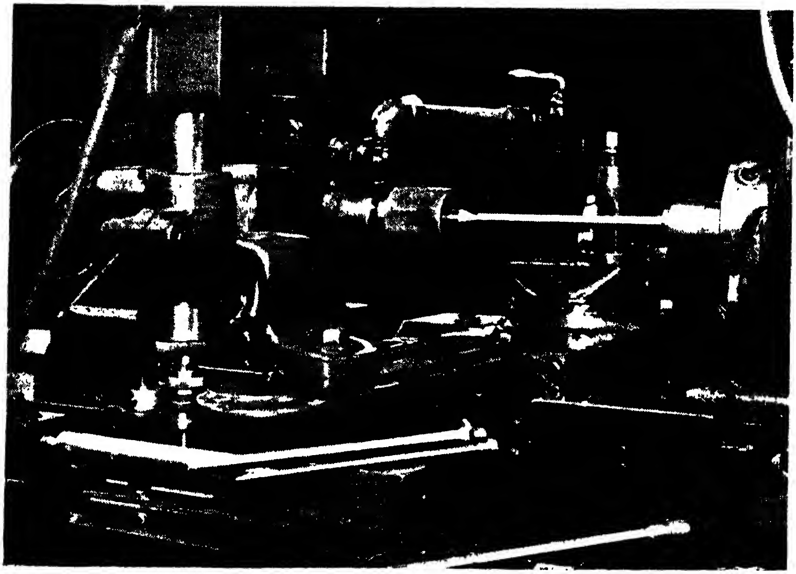

Fig. 5. Machining Irregular Contours

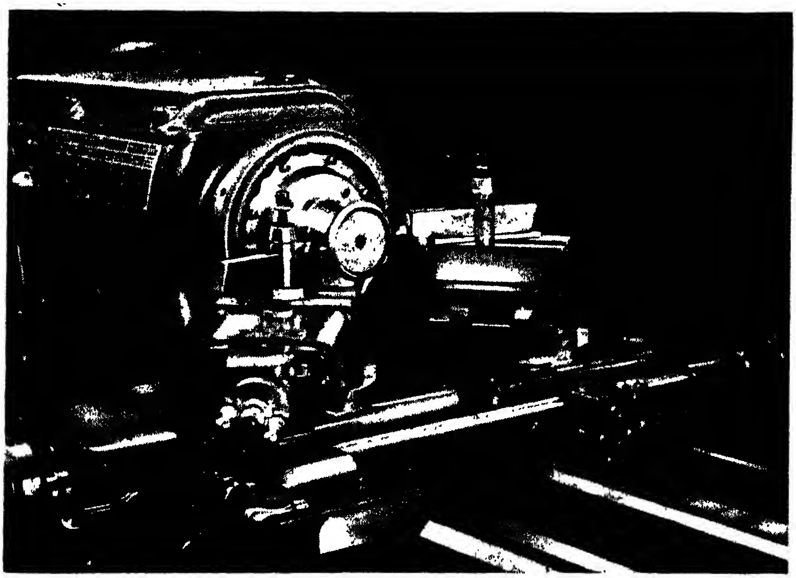

Fig. 6. Turning Angular Surfaces of Bevel Gear Blanks

Turning Bevel Gear Blanks.—Small bevel gears are simultaneously turned on the angular face and edge surfaces, as shown in Fig. 6. This operation is performed on an engine lathe. The cuts are taken by tools mounted at the front and rear of the carriage, which are fed by power across the gear surfaces at the required angles after the carriage has been fed longitudinally to a stop.

Turning Internal and External Spherical Surfaces.—An ingenious method of finishing internal and external spherical surfaces is shown in Fig. 7, the operation being performed on a lathe equipped with the regular compound rest at the front of the cross-slide and a special swiveling tool-head at the back. The part being operated on is a cast-steel leveling socket for an anti-aircraft gun. It is first turned on the periphery to a double taper by using a

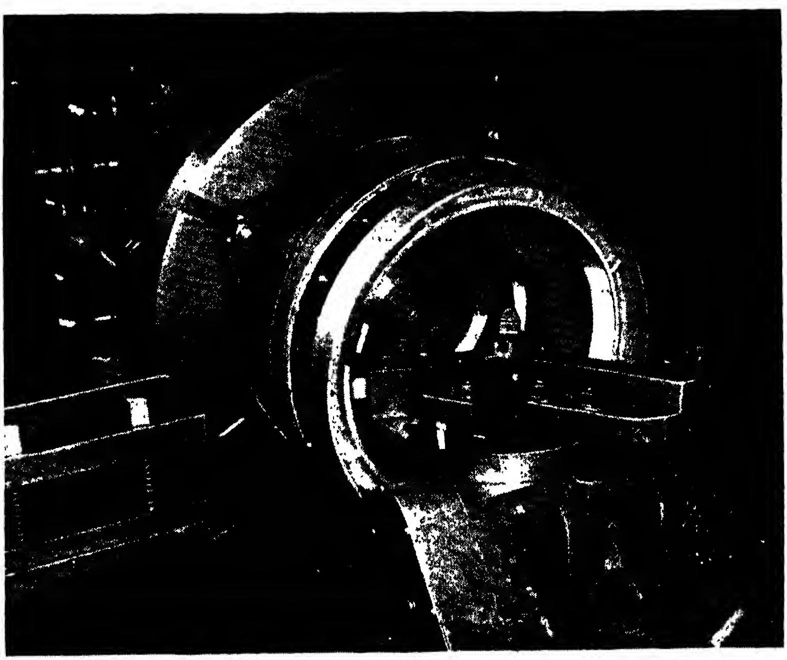

Fig. 7. A Special Tool-head on an Engine Lathe Enables Internal and External Spherical Surfaces to be Machined on Leveling Sockets for Anti-aircraft Guns

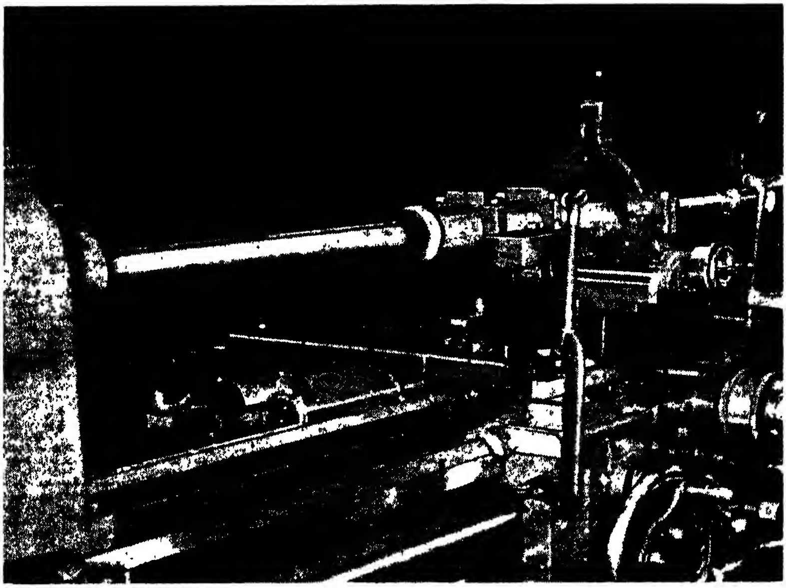

Fig. 8. Boring Hydraulic Cylinder for Landing Gear

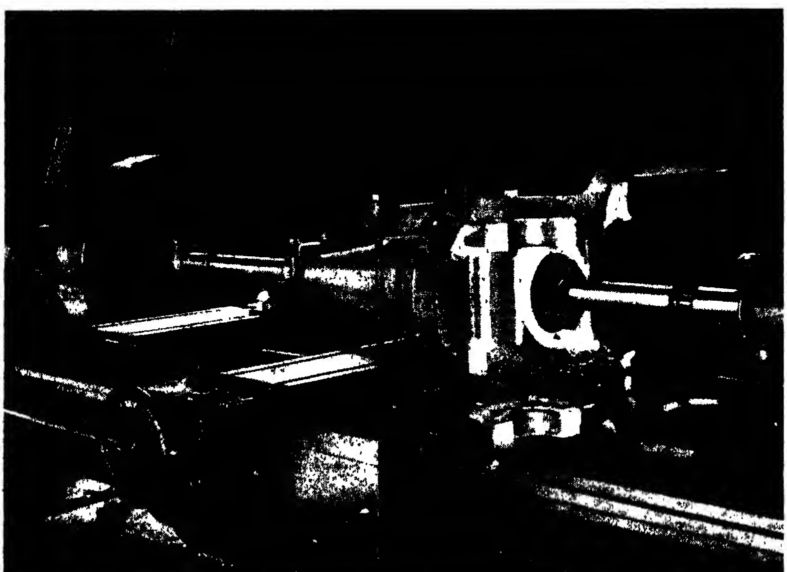

Fig. 9. Boring Part of Anti-aircraft Gun Carriage

tool on the compound rest, after which the special tool-head is positioned as shown for the spherical machining.

The work is then rough- and finish-bored to a radius of 10 inches as two tools on the left-hand side of the tool-head are swiveled around the internal spherical surface by applying the regular power feed of the machine. Upon the completion of these cuts, a hook type tool mounted in the holder seen on the right-hand side of the tool-head is advanced through the work and extended through the hole at the back end of the casting for turning a companion external spherical surface. This surface must be larger in radius than the internal surface by an amount equal to the thickness of the wall and is about 2 1/2 inches long. All dimensions are held within 0.001 inch.

Boring Landing Gear Cylinder.—The unusual lathe set-up illustrated in Fig. 8 is employed for boring landing gear hydraulic cylinders, 27 1/2 inches long, from chromium-molybdenum steel tubing. In order to maintain the bore diameter within a tolerance of plus or minus 0.002 inch, the tubing is mounted on a special block on the lathe carriage, and is given additional support by a steadyrest. One end of the boring-bar is attached to the headstock chuck and driven by the machine spindle, the other end being supported by the tailstock.

In operation, a roughing cut is taken to a depth of 1/8 inch as the carriage feeds toward the headstock, and also a finishing cut, in which stock to a depth of 0.005 inch is removed. After removal from the lathe, the bore is honed to a high finish.

Boring Part of Anti-aircraft Gun Carriage.—One of the operations on the top carriage weldment of an anti-aircraft gun carriage consists of boring it from both ends in a lathe, as illustrated in Fig. 9. The work is supported on two tables of different heights on the carriage, which are provided with suitable rests and clamp blocks. The boring-bar extends from the headstock to the tailstock, and cuts are taken by feeding the work along the boring-bar. Two rough-boring cuts and one finish-boring cut are taken on

the bore at the right-hand end of the work, as seen in the illustration, which is machined to close tolerances.

Both ends of the weldment are also faced in this operation by means of spot-facing tools. The tool for the far end of the work is mounted directly on the boring-bar, which is also true of the boring and reaming cutters, while the facing tool for the near end of the work is mounted on the holder that also carries the boring cutters for this end.

Circular Attachment for Spherical Turning.—Steering-end ball sockets of the "egg cup" design seen at the right in Fig. 10 are parts of a 4-wheel or "quad" drive of an army truck. The spherical surface of these parts is rough- and finish-turned in two lathes provided with special equipment, the illustration showing a lathe used for taking the finishing cut. In this operation, as well as in the preceding

Fig. 10. Steering-end Ball Sockets for the "Quad" Drive are Spherically Turned on Specially Equipped Lathes

roughing operation, the tool-rest is mounted on a circular table which is revolved to carry the cutter around the work in the desired arc. The cutter can be adjusted in and out relative to the work for setting it to the desired radius from the work-center or for changing the depth of cut.

The table is revolved at the desired speed for feeding the cutter around the spherical work surface by the engagement of a large diameter worm-wheel on the under side of the table with a worm mounted on a shaft that extends to the front of the lathe. A grooved pulley on this shaft is driven by belt from a pulley mounted at the front end of the regular cross-slide screw of the machine. The cross-slide screw is driven from the saddle gearing in the usual manner, but the nut of the compound rest is disconnected from the cross-slide screw, so that the compound rest remains idle. Likewise, the lathe carriage remains locked in one position.

By lifting a spring plunger on the handle at the front of the driven pulley on the worm-shaft that drives the swiveling table, the worm-shaft can be disconnected from the pulley and the remainder of the drive. The circular tool-carrying table can then be turned by hand for convenience in setting up the tool.

About 3/16 inch of stock is removed from the spherical surface by tungsten-carbide tools in the rough- and finish-turning operations, the castings having a hardness of about 300 Brinell and the nominal diameter of the spherical surface being 6 3/4 inches. Prior to the turning of the "egg cup," the castings are bored and faced on the opposite end, so that they can be accurately located on the head-stock fixture in machining the spherical surface.

Reaming Operation on Breech End of Anti-aircraft Gun.—The operations involved in machining the chamber surfaces in the breech end of anti-aircraft gun barrels are most important, as all of these surfaces must be concentric with the bore within extremely close limits. This is an especially difficult problem in view of the fact that four of the chamber surfaces are tapered. The chambering operation is performed in an engine lathe. The first cut consists

of rough-boring with a single-point tool to bring the surfaces to size within 0.015 inch.

After roughing the chamber, the first or long taper is bored to the finished size by means of a tangent bar held in a bracket. This bar has a dovetailed groove extending along its length, with a taper corresponding to the bore taper. A bar carrying the boring tool fits snugly into the dovetailed slot, and is pushed along at a suitable feed by a rod extending from the tool-holder on the compound rest. The three remaining tapered surfaces are rough-machined with a reamer. These surfaces are then finish-machined by a reamer having a pilot that registers with the honed bore of the barrel in front of the chamber, as seen in Fig. 11.

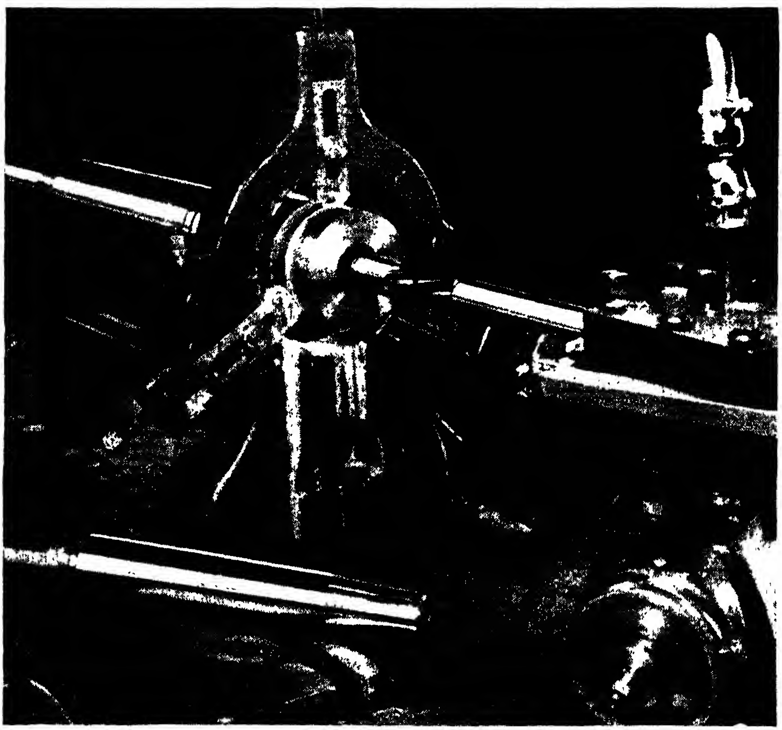

Fig. 11. Reaming the Chamber in the Breech End of the Gun to Fit the Plug Gage Seen Lying on the Lathe Bed, which has Four Surfaces Having Different Degrees of Taper

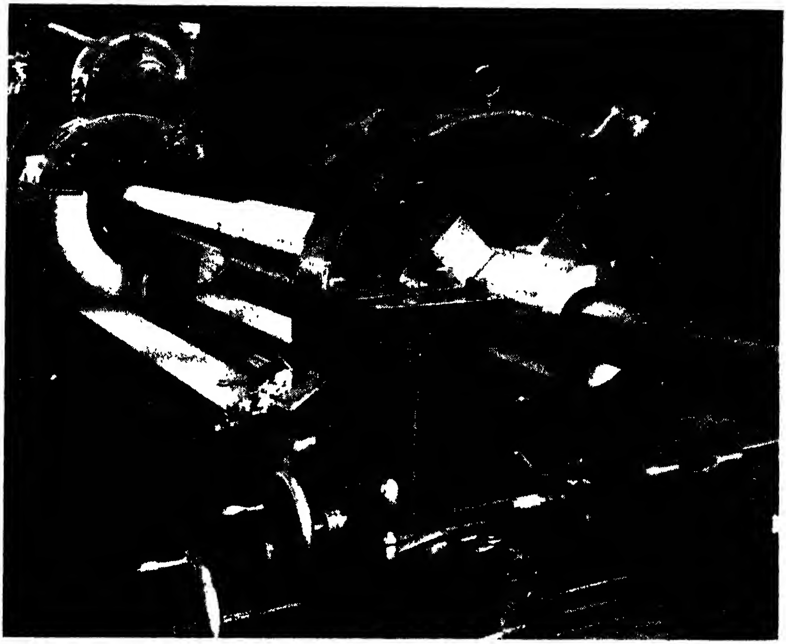

Fig. 12. The Tapered Bore of Anti-aircraft Gun Tubes is Finished by the Use of a Succession of Packed-bit Two-bladed Reamers

Approximately 0.001 inch of stock on the diameter is left on the various chamber surfaces for removal by lapping. The lapping is done by applying different grades of emery paper to an ash stick and passing the stick back and forth along the revolving chamber surfaces until all ridges or scores are removed. The entire chamber must be so smooth after lapping that there will be no minute ridges into which brass can be forced when a shell is discharged, which might interfere with the functioning of the cartridge extractors. To determine whether all ridges have been lapped away, a long cylindrical piece of gutta-percha is squeezed into the finished chamber. If there are any minute metal ridges in the chamber, they will be indicated on the surfaces of the gutta-percha.

An indicator gage seen mounted on the tool-block is used to check the depth of cut taken in boring and reaming the chamber surfaces. The chamber is checked for accuracy

of dimensions by means of four gages, one for each taper, after which a composite gage is employed to check all four tapers at one time. The composite gage may be seen at the front of the machine bed.

Reaming Anti-aircraft Gun Tubes.—The reaming operations to be described follow rough-turning. Step-reaming is done by using fourteen "hog-nose" reamers, which leave a series of cylindrical bores that decrease in diameter from the breech to the muzzle end. The tube is thus prepared for taper reaming. The taper-reaming operation illustrated in Fig. 12 is performed in a lathe equipped with a bed approximately 60 feet in length. In both rough- and finish-reaming, use is made of long packed-bit reamers constructed with a steel arbor to which two long cutting blades are attached, and hard maple blocks that are made to a

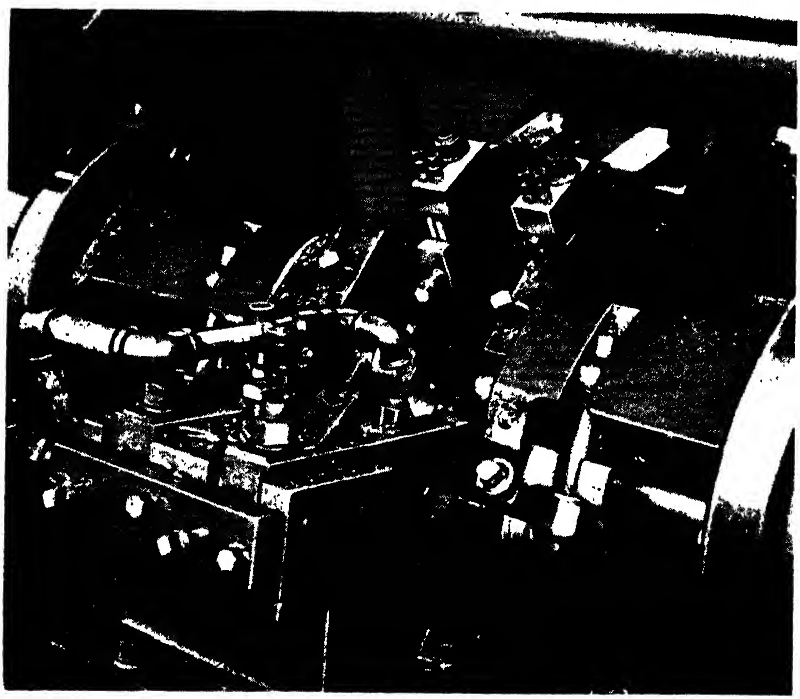

Fig. 13. Crankshaft Lathe Machining the Pin Bearings of Crankshafts for Automobile Engines

diameter slightly larger than the gun bore. The maple blocks are squeezed into the bore and thus hold the tool firmly.

The gun bores are tapered 0.005 inch per inch of length and several taper reamers must be used to ream or "bore" a gun tube for its entire length. In the operation shown, a taper reamer 31 inches long is being entered into the breech end of a 3-inch anti-aircraft gun for reaming the muzzle end. Twelve taper reamers are required for roughing and finishing this gun tube. Each reamer is provided with a brass cylindrical pilot at the front end which engages the rough bore.

Oil at a pressure of 100 pounds per square inch is forced through the long tool-bar and discharged through a number of orifices along the cutting blades. The gun tube bore tapers from 4.584 inches at the muzzle end to 6.119 inches at the breech end. Limits of plus 0.002 inch minus nothing must be maintained on the internal diameters, which are checked every inch of the gun length.

Turning Crankshaft of Automobile Motors.—Fig. 13 shows a crankshaft lathe equipped for turning the crankshafts of an automobile motor. The Nos. 1 and 4 crankpins of each crankshaft are machined in one lathe, and the Nos. 2 and 3 crankpins in a second machine, which is the one illustrated. The two operations are almost identical, except for the fact that the positions of the tool-blocks are different. In both operations, the front and rear tool-slides are fed directly into the work at right angles to its axis. Each crankpin is operated on by a form tool on the front slide and a two-bladed form tool on the rear slide. The rear slide operates after the front slide, and finish-faces the crankpins to the desired length.

Turning Main Bearings of Motor Truck Crankshaft.—In Fig. 14 is shown a close-up view of a Wickes lathe employed for turning five main bearings on a motor-truck crankshaft simultaneously, and for facing the crankpin cheeks adjacent to these bearings. Tools on the front of the lathe carriage are fed straight in for the turning cuts,

these tools being of the same width as the bearings. The facing cuts are taken by tools at the rear of the carriage, which are also fed straight in. Two tools are mounted on each of the rear holders for the facing cuts.

All the tool-holders are adjustable sidewise along the front and rear of the carriage to facilitate positioning them to suit the longitudinal distances between the bearings on different crankshafts. Similarly, the tool-holders can be adjusted in and out for turning to different diameters. The tools can be readily changed to suit bearing widths.

Turning Marine Engine Crankpins.—Fig. 15 shows a lathe employed for finishing the crankpins of marine engine crankshafts. It will be seen that a fixture is mounted on the tailstock end of the crankshaft and on the faceplate of the headstock to provide for revolving the work around any of the three crankpin centers. A large steadyrest that

Fig. 14. Adjustable Tooling on a Crankshaft Lathe Facilitates the Changing of Tool Set-ups to Suit the Various Makes of Crankshafts

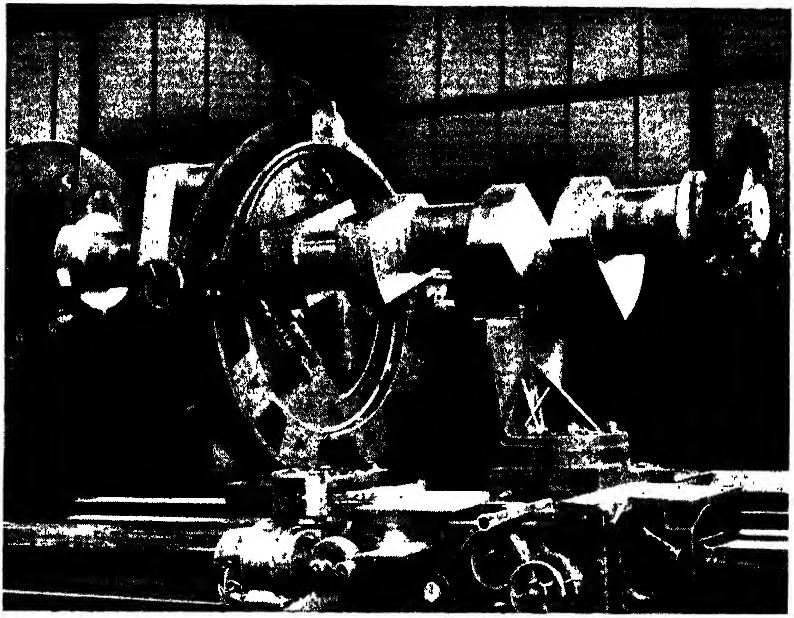

Fig. 15. Machining Marine Engine Crankpins in Lathe

can be adjusted to suit the various centers about which the work must be revolved in machining the different crankpins supports the crankshaft on one of the main bearings. Counterweights are attached to the headstock to insure smooth rotation in turning crankpins. It will be observed that the lathe carriage has an individual rapid-traverse motor drive. Carbide tools are used in machining alloy steel crankshafts, because the tool edges must stand up for the full length of the journal surfaces, in order to obtain the required accuracy. The hardness of these surfaces ranges up to 250 and 260 Brinell.

The flat outer surfaces of the cranks are finished on planer type milling machines after all the main and crankpin bearings have been turned to within 1/8 inch of the finished diameters. This operation could not be performed after complete turning, because the strains that would be released by the probable removal of more surface metal from one flat than from the opposite flat would cause dis-

tortion of the crankshaft, forming a long arc or bow in the length of the piece, and necessitating rectification to a straight line.

Prior to taking the final turning cuts, the crankshaft is either given a stabilizing operation in a low-heat furnace or allowed to season for a prescribed period. After the finish-turning cuts have been completed, the crankpins and main bearings are lapped. All crankpins and bearings of the average crankshaft must be concentric and parallel within 0.001 inch, a tolerance of extreme accuracy when the large diameter of the journals is considered. The phase

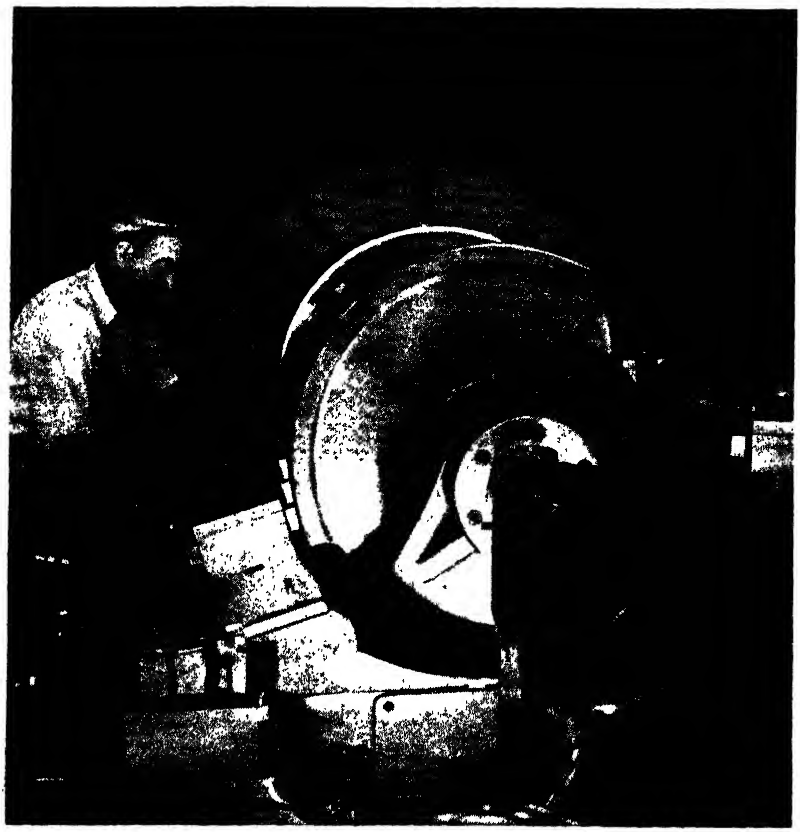

Fig. 16. Turning and Facing Gun Rotors

angle of the cranks must be correct within 1/4 degree on the circle. The axes of all shaft journals must be parallel within 0.001 inch, and the axes of the crankpins must be parallel with the journal axes within 0.0015 inch in 10 inches. The face of the end flange must be square with the axis within 0.001 inch on the diameter. Other tolerances are fully as close as these. A finished solid crankshaft weighs only about 30 per cent as much as the ingot from which it was produced, and a bored crankshaft as little as 12 per cent of the weight of the ingot necessary for safe production.

Turning 75-Millimeter Gun Rotors.—An interesting lathe operation is performed in rough-machining 75-millimeter gun rotors. In this operation, which is shown in Fig. 16, four tools on the front carriage of a lathe are used for simultaneously turning the rotors the full length, after which two cutters on a rear carriage are advanced for facing both ends of the rotors. The castings consist of a long cylindrical section in the center and a large diameter drum-like section that extends halfway around the part. Because of this construction the turning cuts are interrupted, which increases the difficulty of the operation, particularly since the castings are of armor steel. Steady rotation is insured by mounting the work in a heavy fixture that serves as a counterbalance for the unsymmetrical part.

Turning Gear Casting on Vertical Boring Mill.—The vertical boring and turning machine or "mill" belongs to the lathe family, and is very efficient for work within its range. This type of machine is designed for turning and boring work which, generally speaking, is quite large in diameter in proportion to the width or height. The part to be turned and bored is held to the machine table either by clamps or in chuck jaws attached to the table. When the machine is in operation, the table, which has a vertical spindle, revolves and the turning or boring tools remain stationary, except for the feeding movement. Very often more than one tool is used at a time.

Vertical boring mills of medium and large sizes are

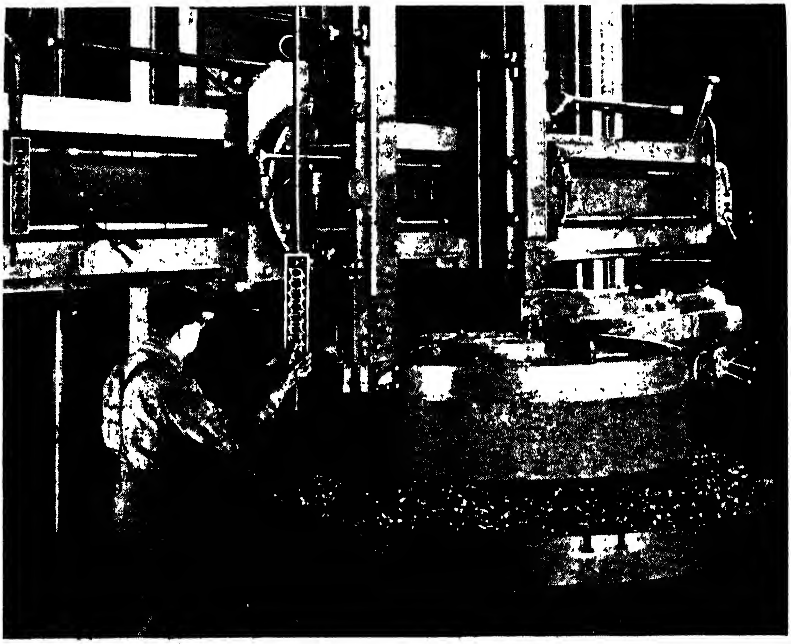

Fig. 17. Machining Gear Casting on Vertical Boring Mill

equipped with two tool-heads on the cross-rail, because a great deal of work done on a machine of this type can have two surfaces operated upon simultaneously. On the other hand, small mills have a single head, and ordinarily the tool-slide, instead of having a single tool-block, carries a turret in which different tools can be mounted.

A typical example of boring mill work is shown in Fig. 17. A heavy gear casting is turned, bored, and faced on the 10-foot boring mill shown. After the casting has been carefully lined up on the table of this machine, a rough-turning cut is taken across the gear face, the central hole is rough-bored, and the top and bottom bosses and rims are faced, the gear casting, of course, being turned over in this operation for machining both sides. Then the casting is again unclamped in order to permit the stresses developed in the rough-machining to be released, after which the casting is carefully reset and clamped for taking

the finishing cuts. Limits of plus or minus 0.001 inch must be held in taking the finish cut in the bore, and limits of plus or minus 0.002 inch on the outside diameter of gears, say, 15 feet in diameter.

Turning Base Ring of Tank Turret.—At the bottom of tank turrets is a base ring, on which the turret revolves when assembled to a tank. This base ring must be accurately turned and faced. The face of the base ring consists of a combination flat surface and a wide bevel that

Fig. 18. Machining Base Ring on the Bottom of the Tank Turrets, on a Vertical Boring Mill

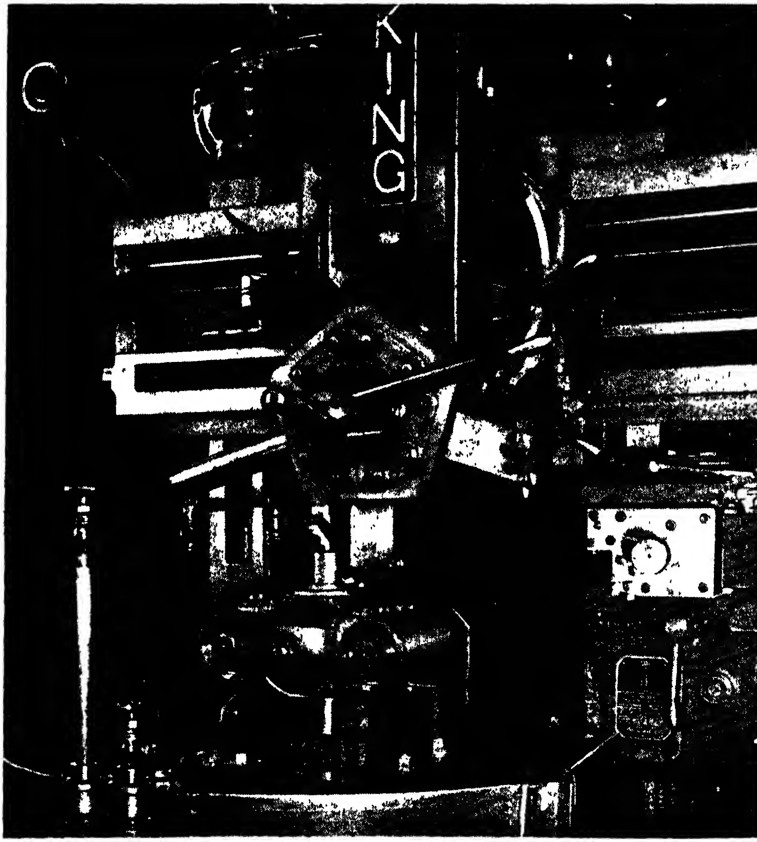

Fig. 19. Turning and Facing Shafts which Project from Opposite Sides of Trunnion Forging

extends about two-thirds across the face. A turning cut is taken by a tool on the right-hand head (see Fig. 18), and then the base is faced by another tool on the same head. A tool ground to the angle of bevel, which is mounted on the left-hand head, is fed straight in horizontally to take a final shaving cut on the bevel. The under side of the base ring is likewise machined to a bevel. The turret is located on a jig for this operation, and screw jacks are used to support it on the short side. A plate clamped on the inside of the base ring centralizes the work at the top with the machine and the fixture.

Trunnion Turning Operation on Vertical Boring Mill.—The shafts of gun trunnions for Army tanks are turned and faced in an operation that is shown in Fig. 19, a vertical boring mill being used. The shafts on both sides of the forging are machined, the work being reversed in the fixture when one side has been finished. Accurate location and clamping of the work is insured in this operation by seating the bores for the two recoil cylinders on large plugs which extend horizontally from the face of the fixture. Cutters on all but one turret station are employed, as well as three cutters on the side-head. The side-head cutters face flange surfaces and the end of the trunnion shaft, all at one time.

Lathes Designed for Turning Duplicate Parts

The lathes shown in this section are intended primarily for producing duplicate parts in connection with manufacturing operations. This general type of lathe is often referred to as an "automatic lathe" and sometimes as a "manufacturing" type. These lathes are not fully automatic or capable of repeating automatically a given cycle of operations as on an automatic screw machine. All tool movements may be automatically controlled but the work must be inserted and removed manually. These manufacturing types are efficient for turning comparatively short parts. Multiple tooling is a characteristic feature; a number of tools usually being employed at the same time. There are both front and rear tool-blocks in order to machine all surfaces simultaneously. Lathes of this general class are especially adapted for turning parts held between centers and for second-operation work on parts held on arbors.

Rough-turning "25-Pounder" Shells.—Rough-machining of 25-pounder shells is performed in lathes tooled up as shown in Fig. 1. This illustration also shows the appearance of the rough forgings as they reach this machine. Six tools on the front carriage take turning cuts simultaneously, five of them along a straight path and the one at the extreme right at an angle to form the taper at the base end. A carbide cutter is used for the heavy taper cut, and it is fed at the desired angle through a spring action which holds the forward end of the tool-block against the contour surface of a bar type cam. This cam is held sta-

tionary by being attached to the tailstock. Each turning tool takes a cut about 2 1/2 inches long.

While the turning cuts are in progress, two tools on cam-operated tool-blocks at the rear of the machine feed forward to face the base end of the shell and to cut off the excess stock on the nose end. Each shell is loaded on a loose mandrel before it is placed in this machine, the loose mandrel contacting an arbor that extends from the headstock chuck. The chuck arbor is provided with expanding jaws that grip an inside surface of the mandrel for driving purposes.

The opposite end of the shell is supported by the tailstock center, which is moved into position by air. When the tailstock center presses against the end of the shell,

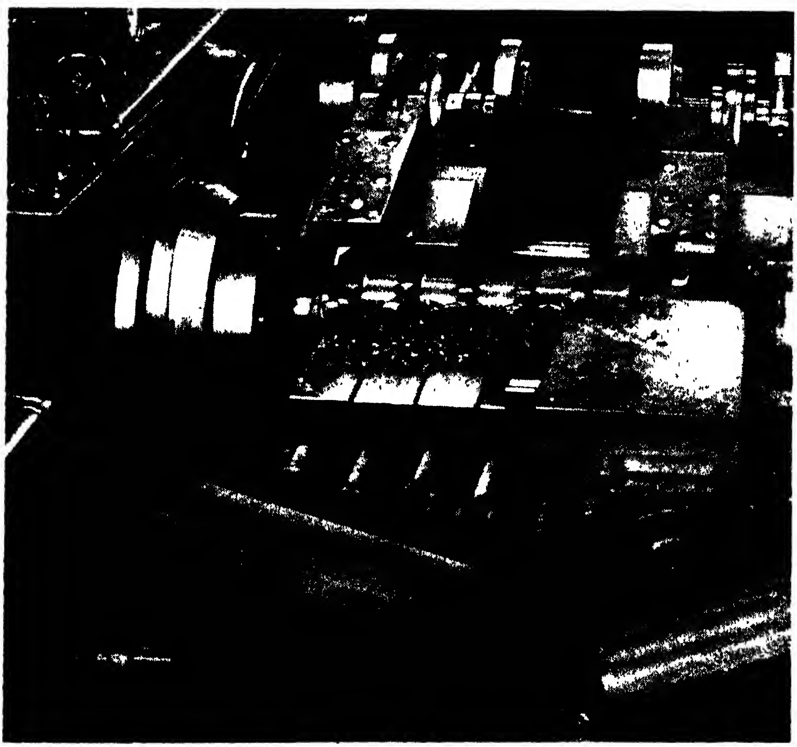

Fig. 1. Rough-turning the Shell Forgings, Facing the Base End, and Cutting off the Nose End in an Automatic Lathe

the mandrel is pushed firmly endwise against the arbor of the chuck, thus forming, in effect, a mandrel that is solid with the chuck arbor. The use of loose mandrels accurately positions the work and controls the tailstock movements which are necessary for reloading. The chuck is also air-operated. Soluble oil is supplied to the tools and work in this operation at the rate of 75 gallons a minute.

From the rough-turning operation, the shells go to a gas-fired furnace where they are heated to approximately 1832 degrees F. for a length of about 4 inches from the open end preparatory to a bottlenecking operation.

Finish-turning "25-Pounder" Shells.—The shells next pass to lathes tooled up as illustrated in Fig. 2 for finish-

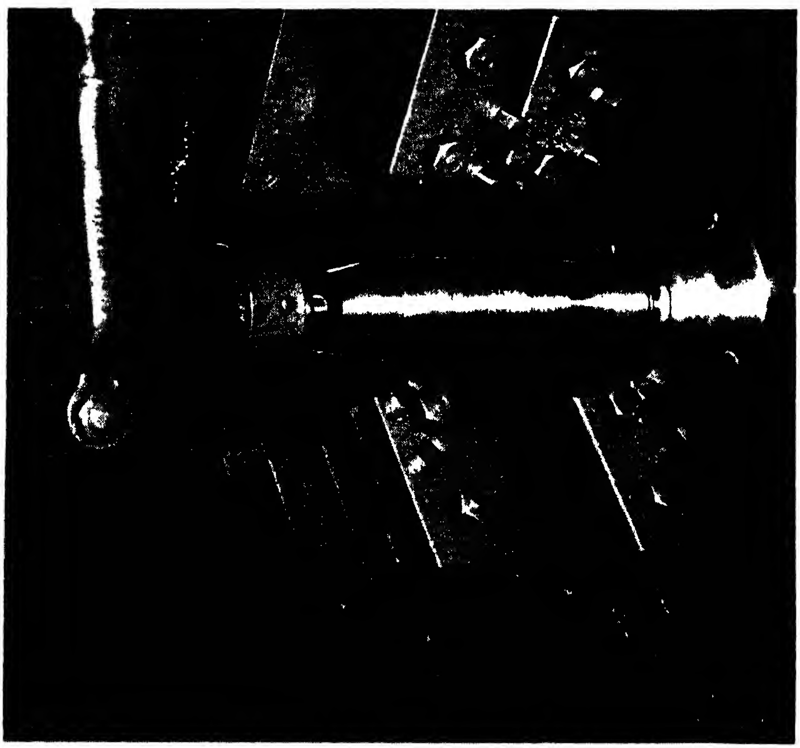

Fig. 2. Shells are Finish-turned Straight in Center and Tapering at Both Ends in Automatic Lathe

turning. Two tools are mounted on the front carriage and two on the rear carriage. The left-hand tool on the rear carriage rough-turns the taper on the base end of the shell, while the right-hand tool finish-turns the nose end. At the same time, the left-hand tool on the front carriage finish-turns part of the straight portion of the shell and the taper at the base end. The right-hand tool finish-turns the straight portion from the point where the nose taper ends to the point where the left-hand cutter starts turning.

Stationary cam bars are provided for both the front and rear carriages to control the movements of the three tools that take tapering cuts. These cam bars are connected to the tailstock and cause the tool-blocks to be fed forward or to be withdrawn, as required. Carbide tools are employed for the four cuts. The shell is mounted on an air-operated expanding mandrel, and the tailstock spindle is also moved back and forth by air. Each machine finishes an average of thirty-eight shells per hour.

At this point in the manufacturing procedure, the marks previously placed on the billets to indicate the heat and mill in which the steel was produced, which have been machined off, are again stamped on, together with the code of the manufacturer in whose shop the shells are being made. The shells are also weighed to make certain that they are being produced within the specified weight limits.

Finish Turning 75-Millimeter Shells.—The finish-turning operation to be described is performed on an automatic lathe as shown in Fig. 3. Before this operation, however, a threaded plug or adapter is screwed into the tapped opening of the shell. The adapter is center-drilled on the side opposite its threaded shank to provide a means for supporting the nose end of the shell on the headstock center of the machine, while the other end is supported by the tailstock center. This makes it possible to finish-turn the shell in close concentricity with the forged shell interior. The concentricity must be within 0.015 inch at all points.

Finish-turning of the shell is performed by three tools on the front carriage of the automatic lathe. The tool seen in the foreground is pulled radially outward as it feeds

along the work, so as to turn a taper above the base end of the shell, and then it moves in a straight path for cylindrical turning. The next tool remains in one position on the carriage, because it turns a straight cylindrical surface only. The third tool moves parallel with the shell center line for a short distance for cylindrical turning, and then is fed radially toward the center of the machine to finish the tapered shell nose.

The in and out movements of the first and third tools are obtained through the use of a profile or cam bar. This bar is mounted on the tool-slide, but is held in a stationary position, as it is attached to the tailstock of the machine,

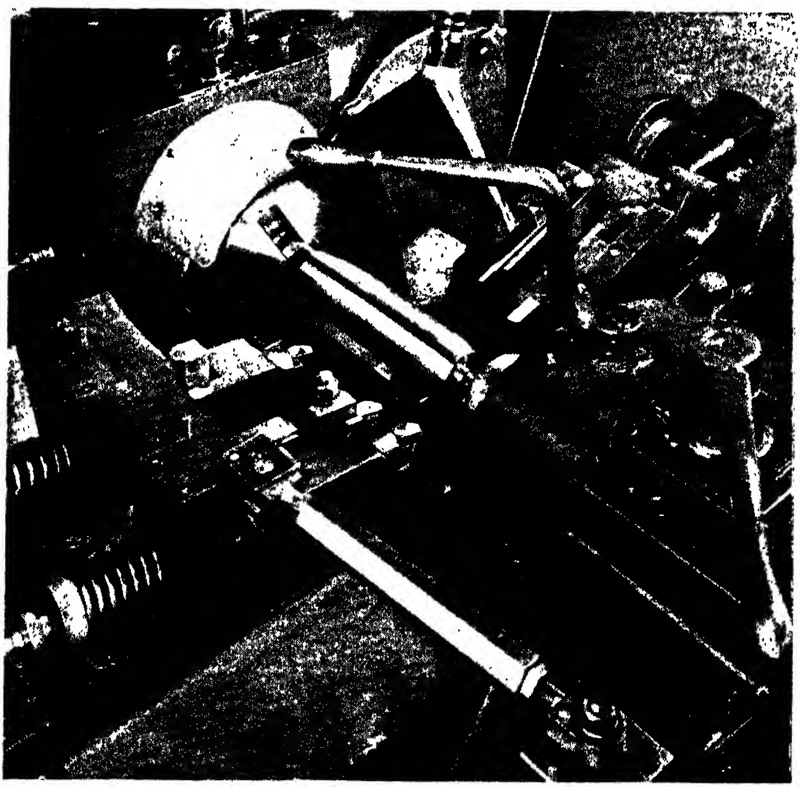

Fig. 3. Automatic Lathe and Tooling Equipment Used for Finish-turning, Facing, and Grooving Operations on the Shells

while the tool-block moves longitudinally with the carriage. Rollers attached to the tool-holders follow the changing contour of the cam bar and impart corresponding in and out movements to the tools. Helical springs hold the rollers firmly against the cam bar.

While the turning cuts are in progress, two tools at the rear of the machine slide forward under the control of a circular cam to face the base end of the shell and start forming a rifling-band groove. Excellent production has been obtained by the use of tungsten-carbide tools. The work runs at 400 R.P.M., and about 3 32 inch of stock on the diameter is removed at a feed of 0.020 inch.

Rough-turning of the shells is performed on automatic lathes tooled up somewhat similarly to the machine illustrated. Rough-turning is also an important machining operation, due to the final concentricity requirements, and to the fact that, in the boring and threading operations on the nose end, the shell is located from the rough-turned surface.

Turning Rifling Band Groove on Shell. — The rifling-band groove and a narrow groove adjacent to it, which is used in crimping on the cartridge case, are finish-formed by tools on the front slide of the automatic lathe illustrated in Fig. 4; the front slide is seen at the left of the illustration. A second tool on this slide faces the base end of the shell. Both tools are fed straight in for the operation. At the end of the front-slide movement, two tools at the rear slide, on the right, are brought into action. One of these tools, which is ground for forming four annular threads in the rifling-band groove, is fed tangentially to the bottom of the shell in the manner of a skiving tool. Above the skiving tool, positioned centrally in relation to the work, is a circular knurling tool for pressing grooves at close intervals across the annular threads.

In loading this machine, the tailstock center is brought against the base end of the shell by hand. Then, as the rear tool-slide starts advancing in synchronism with the front slide at the beginning of an operation, a valve is tripped to admit air to a cylinder within the tailstock in

back of the quill that holds the center. With this arrangement, the tailstock center is held firmly against the work by air pressure during the operation. When the rear tool-slide recedes to its starting position, the valve is tripped to release the air pressure and permit the tailstock center to be withdrawn by hand. Both the front and the rear tool-slides are actuated hydraulically. All the cutters used in this operation, with the exception of the knurling tool, are tungsten-carbide tipped.

Rough- and Finish-turning Cylindrical Part of Shell.— The automatic lathe shown in Fig. 5 is used for rough- and finish-turning the cylindrical portion between the nose and

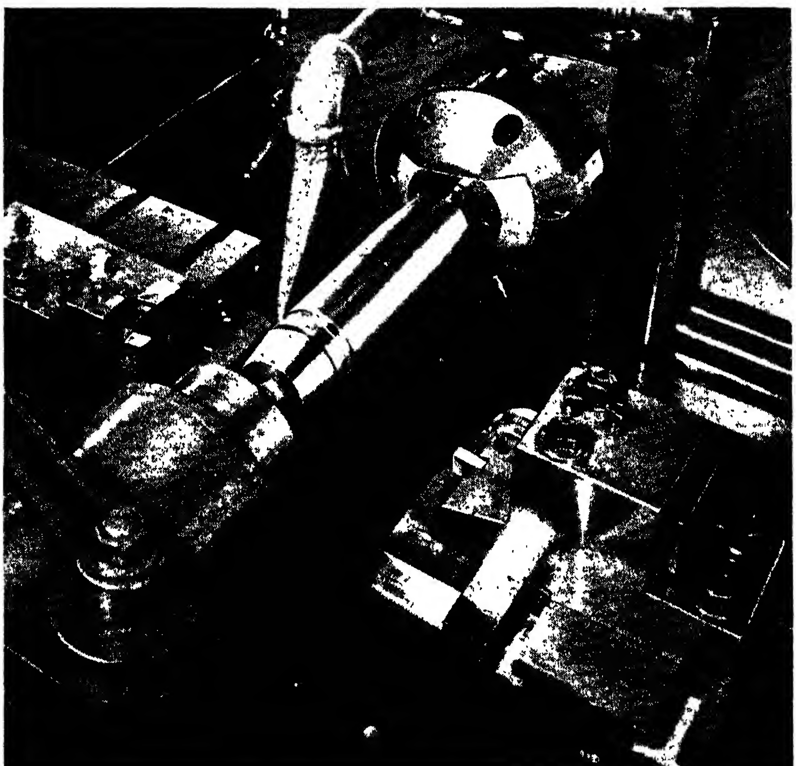

Fig. 4. Automatic Lathe that Finish-forms, Skives, and Knurls Rifling-band Groove, Forms the Crimping Groove, and Faces the Closed End

tail ends of the shell. The rough-turning operation is illustrated. There are three cutters on the front carriage and three on the back arm, all of which are employed for turning straight surfaces. The finish-turning machine is equipped with three cutters on the front carriage only. These cutters finish the body of the shell and the bourrelets at opposite ends to two different diameters. The limits on these surfaces are plus 0.005 inch, minus nothing.

Turning Cast-iron Flywheels.—Flywheels and ring gears for automotive applications are machined in the lathe illustrated in Fig. 6. The operation shown is the second one

Fig. 5. Tooling Equipment Provided on Automatic for Rough-turning Body of Shell and Both Bourrelets

performed on cast-iron flywheels, the work being chucked on a surface that is finish-turned in a preceding operation.

In the operation illustrated, six tools on the front slide are employed for rough-turning, boring, and facing cuts, while four tools on the rear slide finish-shave three surfaces and turn one diameter, and two tools on the piloted center slide chamfer the bore of the flywheel and size the counterbore. In addition, a tool on the overhead piloted bar, which is actuated from the center slide, sizes a ring gear surface.

Stellite J-metal tools are used for the entire operation. The feeds range from 0.005 to 0.037 inch. Two peripheral speeds of 55 and 100 surface feet per minute are used. The floor-to-floor time in this operation is four minutes.

Use of Cam Bar for Contour Turning.— Torque-rod pin forgings are turned in the Lo-Swing automatic lathe, shown

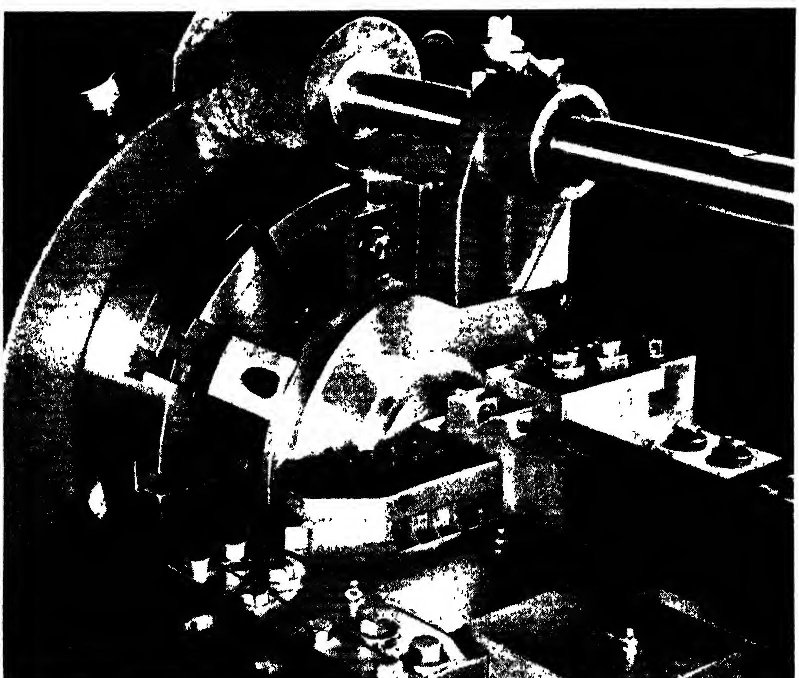

Fig. 6. Finishing Flywheels

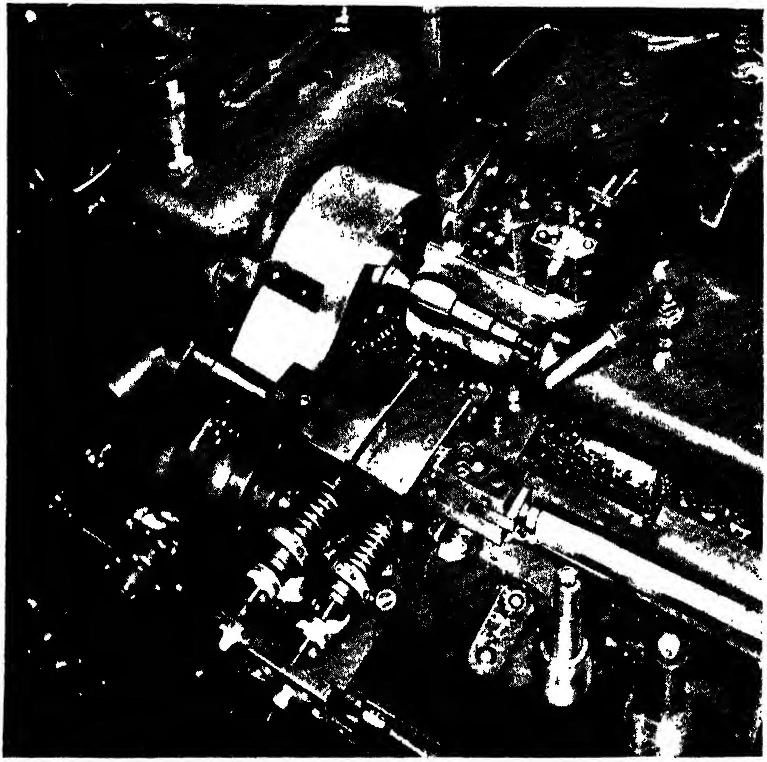

Fig. 7. Automatic Lathe Equipped for Turning Torque-rod Pins of High Brinell Hardness

in Fig. 7. Three tungsten-carbide cutters on the front carriage turn the large, elliptical shaped end of the part, a tapered length to the right of the elliptical head and a smaller-diameter cylindrical portion at the right-hand end. The taper and ball-end turning tools are moved in and out in relation to the work as the carriage is fed along the bed. This cutter movement is produced by rollers attached to the quills that carry the tools riding on a cam bar on the carriage. The cam bar is fastened to the tailstock so that it is held stationary as the carriage moves longitudinally.

While these turning cuts are being taken, three cutters on a slide at the rear feed forward to face and chamfer

both ends of the part and also to face the shoulder where the taper and elliptical portions end. The limits on the diameter of the elliptical end are 2.305 and 2.320 inches. It has a radius of 2 3/8 inches. The over-all length of the part is 5 3/4 inches. It is made of S A E 4340 steel and has

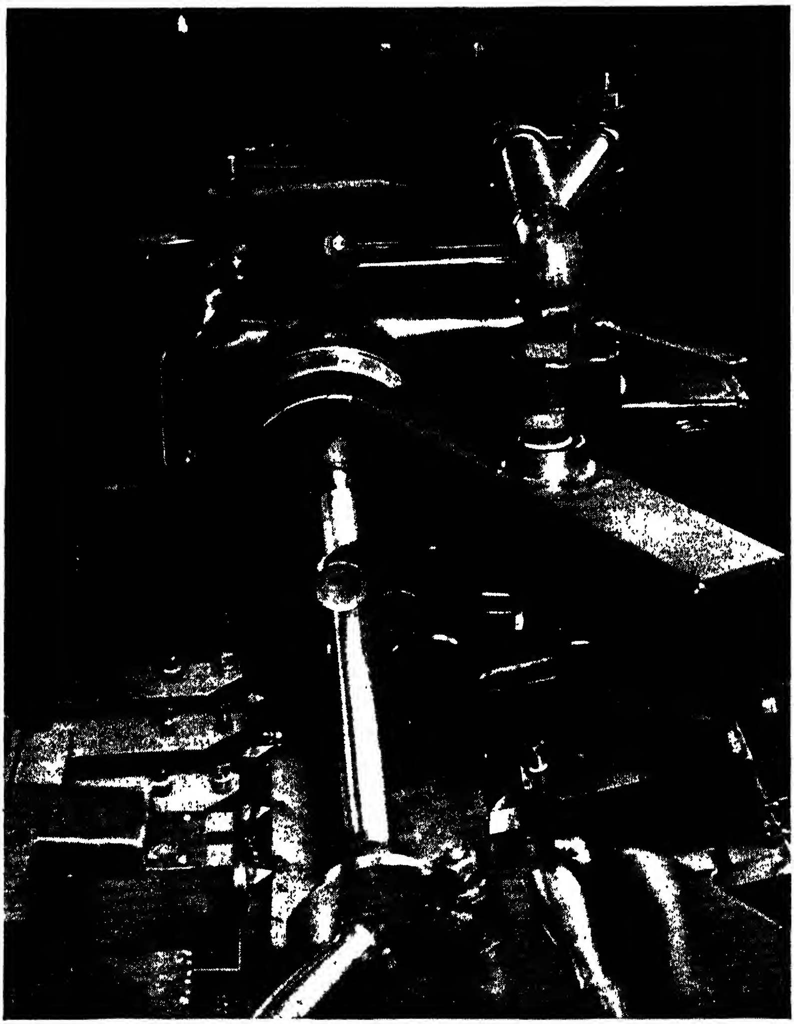

Fig. 8. Tooling Equipment Provided on an Automatic Lathe for Rough-turning Machine Gun Barrels

a Brinell hardness of 330 to 375. All the tools used in this operation are of tungsten-carbide.

Rough-turning Machine Gun Barrels.—Before rough-turning, a width of approximately 1 1/4 inches is ground in the middle of the barrel stock to provide a finished surface for a roller rest employed in rough-turning the stock. This grinding operation is performed on a machine of the standard cylindrical type. The barrels are next rough-turned in an automatic lathe equipped, as shown in Fig. 8, with four cutters on the front carriage and one cutter on the rear slide. Three of the cutters on the front carriage machine a cylindrical surface, each cutter being moved longitudinally a distance of 3 inches. The fourth cutter, which appears in the left foreground, cuts cylindrical surfaces to two diameters. This is accomplished by the cutter being pulled toward the front of the carriage as a roller on one end of the quill which holds the tool rides along a stationary cam bar during the feed of the carriage along the bed. While the cutters on the front carriage are in action, the cutter on the rear slide advances to chamfer the barrel.

When one half of a barrel has been turned, the barrel is reversed in the machine and the opposite end turned. All tools are tipped with tungsten carbide. The barrel is supported near the center by a roller rest. After being rough-turned, the barrels are finish-turned in a similar automatic lathe.

Turning Brake Spiders.—Brake spiders are rough- and finish-turned on 12-inch automatics. A finished spider is seen supported between the centers of the machine in Fig. 9. The illustration shows the finish-turning operation. In both rough- and finish-turning, the spider forging is supported on an arbor that is slipped into previously machined bores in the part.

The rough-turning automatic is equipped with nine cutters on the front carriage, five of which are applied for turning a taper surface, and two for turning straight cylindrical surfaces, all on the shank. The eighth tool is used for turning a pilot shoulder on one side of the flange,

and the ninth for turning the flange. The taper turning tools are traversed in an angular direction by a cam bar. Three cutters on an arm at the rear of the machine face the two sides of the flange and a shoulder.

The finish-turning automatic, shown in the illustration, is equipped with seven tools on the front carriage for machining six straight cylindrical surfaces on the shank and one on the flange. Three tools are provided on the rear arm for finish-turning the surfaces that were rough-faced in the previous operation. About 1/8 inch of stock is removed in roughing. Tolerances on finish-turning range from 0.004 to 0.010 inch.

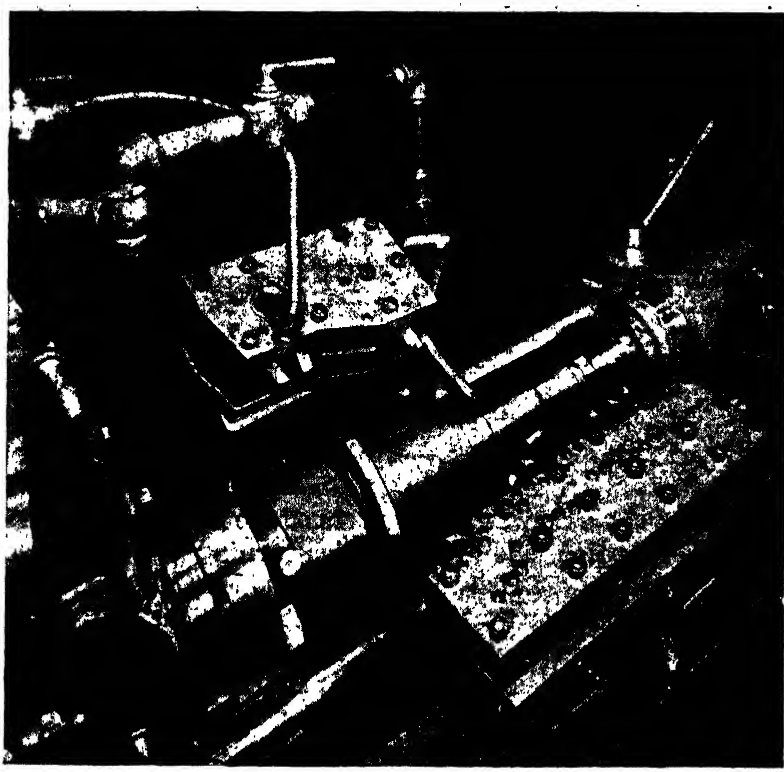

Fig. 9. Automatic Lathe Used for Finish-turning Brake Spiders after they have been Rough-turned with Similar Equipment

Rough-turning Landing Gear Cylinders.—The use of multiple tooling for taking a number of cuts simultaneously is typified by the operation illustrated in Fig. 10, which shows a 12-inch automatic lathe rough-turning the cylinders for the operating struts of hydraulic landing gear. These cylinders are made from chromium-molybdenum seamless steel tubing, 3 3/4 inches outside diameter and 3 inches inside diameter. Six tungsten-carbide tools are mounted on the front carriage, five of them taking turning cuts to the same diameter, and the sixth to a slightly larger thread diameter on the end that is held by the tailstock.

Two cutters are provided on the back arm, one of which

Fig. 10. Automatic Lathe Set up for Machining Operating Strut Cylinders for Hydraulic Landing Gear

cuts a fillet near the headstock end of the work when the back arm swings forward, while the second tool chamfers the tailstock end of the work at the same time.

Spherical Turning Operation.—The operations to be described are on the spherical trunnion sockets that are assembled into the ends of the front axles for "quad" drives of Army trucks. These trunnion sockets are machined to a true sphere in automatic lathes tooled up as shown in Fig. 11, after the shank end has been finish-turned, as seen on the piece at the right on top of the headstock.

For the spherical turning operation, the work-piece is slipped on a stub-arbor attached to the headstock spindle. The turning tool is mounted at the rear of the machine on a holder that is pivoted below the center of the trunnion

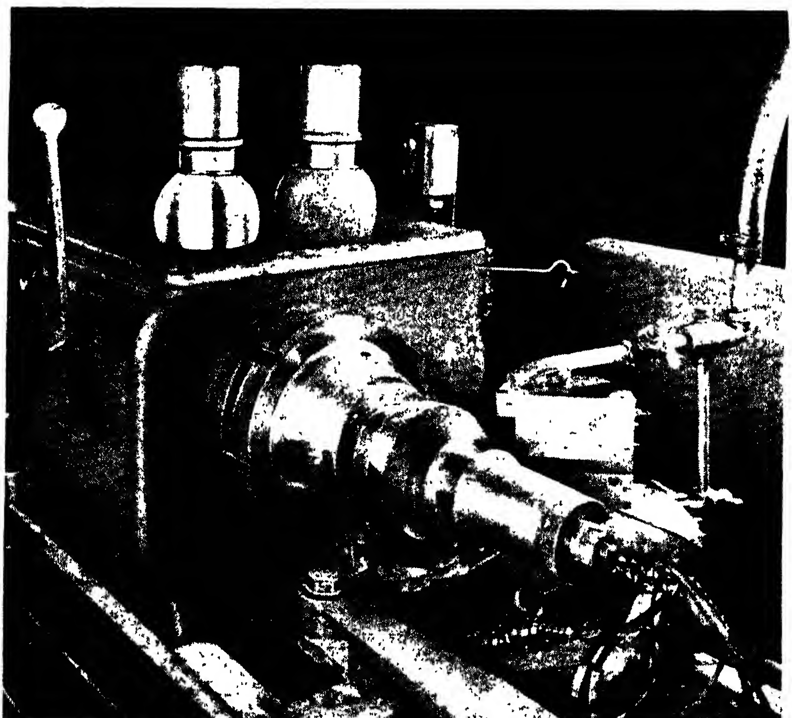

Fig. 11. Automatic Lathe Tooled for Turning a Spherical Surface on Steel Trunnion Sockets

socket. This holder is swung around its pivot, with the tool positioned to finish the socket to the required radius, as the machine carriage is fed along the bed. The pivoting action is produced by a link which is attached to the left-hand end of the carriage and to one end of the pivoted tool arm. A cut from 1/4 to 5/16 inch deep is taken with a tungsten-carbide tipped tool.

Rough-turning 3.7-Inch Shells.—The rough-turning of 3.7-inch shells is performed in 16-inch automatic lathes equipped as illustrated in Fig. 12. Four tools on the front carriage are moved along the shell for the turning cuts. The two tools at the right move along a straight path, the third tool from the right is given an in-and-out movement to turn an irregular contour, and the fourth tool, at the

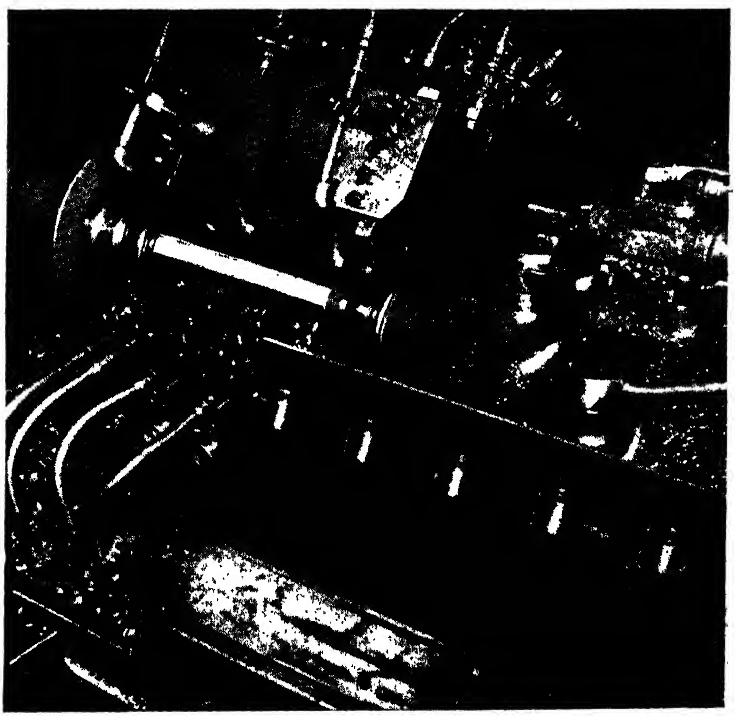

Fig. 12. Rough-turning 3.7-Inch Shells to an Irregular Contour, Facing the Base and Cutting off the Nose End

extreme left, is fed forward at a constant rate for turning a taper on the nose end. The action of the third and fourth tools is accomplished through the use of a stationary former slide which extends through the carriage and against which the tool-slides are held by positive follower shoes. Two tools on the back carriages rock forward to face the base end of the shell and to cut off the open end to length.

A feature of this machine is the provision for quick reloading of the shells. At the end of an operation, the hinged tailstock automatically swings upward into the position shown in Fig. 13, so that the shell can be removed from the driving fixture attached to the headstock spindle and a rough forging slipped on this fixture without any end-

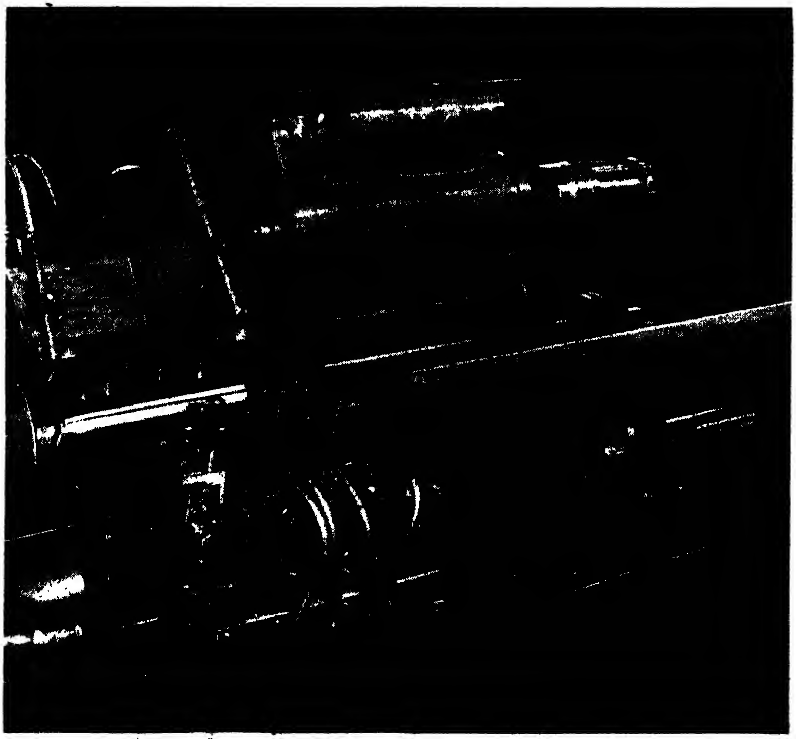

Fig. 13. The Tailstock on Automatic Shell-turning Lathes is Automatically Swung up by Hydraulic Pressure to Facilitate Loading the Shells on the Headstock Mandrel

wise movement of the tailstock. When the tailstock swings upward, a sheet-metal trough at the front of the machine, which is fitted with conveyor rollers, automatically swings backward into line with the finished shell. The shell can then be pushed readily along these rollers and a rough forging previously placed on the trough slipped on the headstock fixture. The tailstock then automatically swings forward into the working position and its spindle moves to the left to bring the center against the end of the newly loaded shell. The swinging action of the tailstock is accomplished by hydraulic power, and the gripping members of the fixture are also operated hydraulically. The tailstock spindle is advanced and withdrawn by hydraulic pressure. All the tools used on this machine are tipped with tungsten carbide.

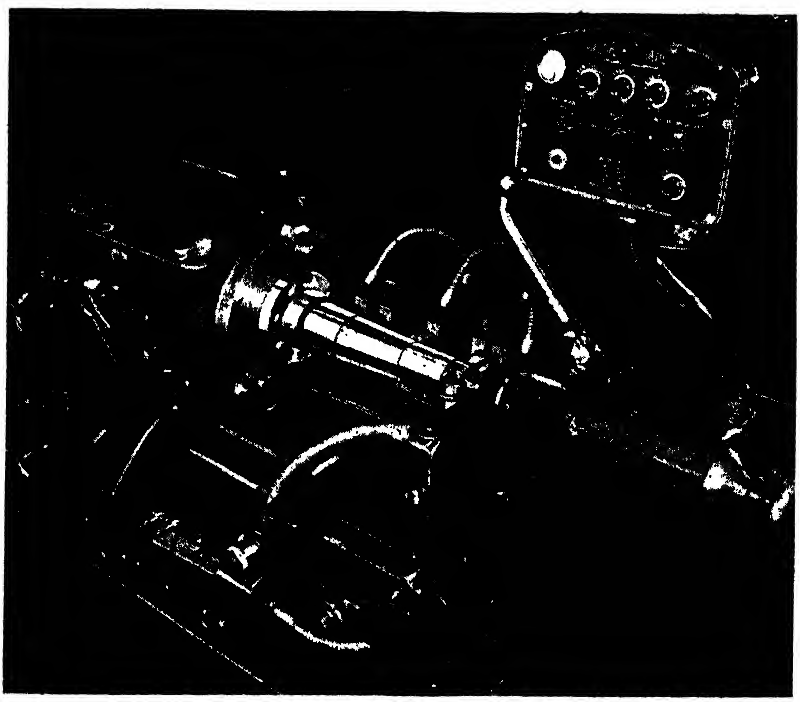

Fig. 14. Multiple Tooling Provided on Electrically-controlled Lathe for Machining Tank Final Drive-shafts

Turning Shafts on Automatic Lathe with Electrical Control.—The final drive-shafts for army tanks are turned in a lathe tooled up as shown in Fig. 14. Turning cuts are taken on the straight and tapered surfaces by tools on the rear carriage, which also face two shoulders and chamfer the end. A tool on the front slide faces the end. The automatic operation of the tool-slides is governed by the electrical control board at the rear of the machine. These parts, which are chromium-nickel forgings, are machined in this operation at the rate of forty minutes per piece.

Magnetic clutches control both the feed and traverse of the front carriage, and of the front and rear tool-slides. There is also a magnetic clutch and brake for the spindle. Cams are not used in the operation of this lathe. Diameters and lengths of cut are controlled by limit switches.

The master control switch, shown in the elevated position at the tailstock end of the machine, gives a complete electrical control for both setting up and full automatic operation. The main starter button starts the feed of both carriages, in addition to starting the spindle. One button will reverse both carriages at any point in the cycle of operations, the carriages then returning quickly to their starting positions. Another button controls the front carriage and provides an "inching" movement to the front tool-slide and carriage for convenience in setting up. Another button gives an "inching" movement to the rear tool-slide. The cycle of the rear carriage can be timed before or after the front carriage cycle or at any intermediate point in relation to it. In changing from one job to another, it is merely necessary, in addition to changing the tool set-up, to set micrometer stop-dogs for "in" and "out" front tool-slide diameter, for front carriage "length travel," and for rear carriage "in" and "out" feed travel.

Typical Machining Operations on Turret Lathes

The turret lathe is used in the manufacture of duplicate parts and is especially useful whenever machining requires a succession of tools for operations such as turning, facing, boring, drilling, reaming, etc. The characteristic feature of the turret lathe is that after being "tooled up" for a given job, all the necessary tools can be quickly and accurately located in their respective working positions. (The expression "tooling up" indicates the selection of the right types of whatever standard or special tools may be required for a given job and the proper location of these tools on the machine in order to perform each operation in whatever sequence or order will give the best results.) Most of the tools required are held by a turret which is indexed around to locate successive tools in the operating position. In the use of ordinary turret lathes, the movements of the tools not obtained by the feeding mechanism, such as adjustments toward or away from the working positions and the indexing of the turret, are manually controlled. When a machine is designed to control all of these movements automatically, it belongs in the automatic group which is featured in a section to follow. Turret lathes are used for an endless variety of operations in the manufacture of mechanical products. The few examples in this section are intended merely to illustrate typical applications.

Turning and Boring Landing Gear Cylinders.—In machining the landing gear for airplanes, the cylinders and pistons may require limits of plus or minus 0.005 inch. Landing gear cylinders are received in the form of solid forgings, as shown by the example seen lying on the ways of the

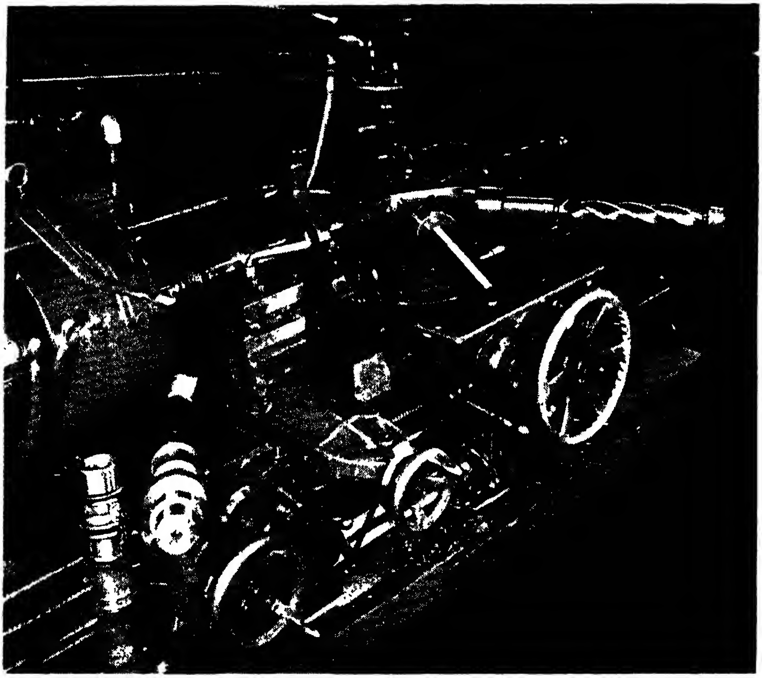

Fig. 1. Machining Landing Gear Cylinders in Turret Lathe

cross-slide carriage of the machine illustrated in Fig. 1. These forgings weigh 120 pounds when they reach the plant, and only 24 pounds when finished, a reduction in weight of 80 per cent being effected.

The solid cylinder forgings are drilled the full length by means of an oil drill, 2 11/16 inches in diameter, having a fluted length of 28 inches. The forging is then rough-machined all over in a turret lathe, after which it is heat-treated to a hardness of 38 to 41 Rockwell C. It is then brought to the heavy-duty turret lathe shown in Fig. 1, for finish turning and boring, an operation in which 0.020 inch of stock is left on the diameter of both internal and external surfaces to be removed later by grinding.

In the turret lathe operation shown, the first cut is taken by a short two-bladed boring-bar on the turret, which starts a hole in the end of the cylinder, the work being supported

by the headstock of the machine and a steadyrest which engages a short surface previously turned. The turret then indexes, bringing a long two-bladed boring-bar into line with the work for boring a hole 3 1/16 inches in diameter to a depth of 23 7/16 inches, in the case of the particular cylinder being machined. At the end of this cut, the first long reamer seen on the turret is indexed into place for reaming the hole to its full depth, and then the other reamer takes a second cut on the hole.

The fifth turret tool bores a thread surface, this tool being mounted on a turret-slide so that it can be adjusted at the end of the boring cut for chamfering the end of the hole. While these cuts are being taken, the outside of the cylinder is completely turned by tools on the front tool-post, except for the surface supported in the steadyrest. The pistons for landing gears are turned and bored in a similar manner on the same type of machine.

Turning Parts from Aluminum Alloy Bar Stock.—Fig. 2 shows a turret lathe being employed for producing bulk-head nipples from 1 3/4-inch hexagonal aluminum alloy bar stock. One of the finished pieces is seen resting on the hexagonal turret. In this operation, the stock is first fed to a stop on the hexagonal turret, after which the end is turned by means of a tool on the square turret at the front of the cross-slide. Then a forming cut is taken with a second tool on the square turret, and the corners of the hexagon stock are chamfered with a third tool on the square turret.

The end of the bar is next center-drilled with a tool on the hexagonal turret and then drilled to 3/4-inch diameter by means of a drill on the third face of the hexagonal turret. Next a 1 1/8-inch drill on this turret cuts to a depth of 2 1/16 inches, this operation having just been completed when the photograph was taken. Finally, the part is cut off from the bar by means of a tool that is mounted on the rear of the cross-slide.

Machining Packing Gland Nuts.—A turret lathe tooled up for machining packing gland nuts from solid duralumin

bars 5 3/4 inches in diameter is shown in Fig. 3. One finished nut is seen on top of the turret. In this operation, the stock is fed to a stop on the first turret face, after which a flat drill on the second turret face drills the piece to a conical seat. The flat drill is seen in the center of the illustration. The tools on the third turret face, at the left, next turn the end of the stock and bore it near the inner end of the drilled hole to a diameter somewhat smaller than that produced by the drill, so as to leave a flange on the piece when it is cut off.

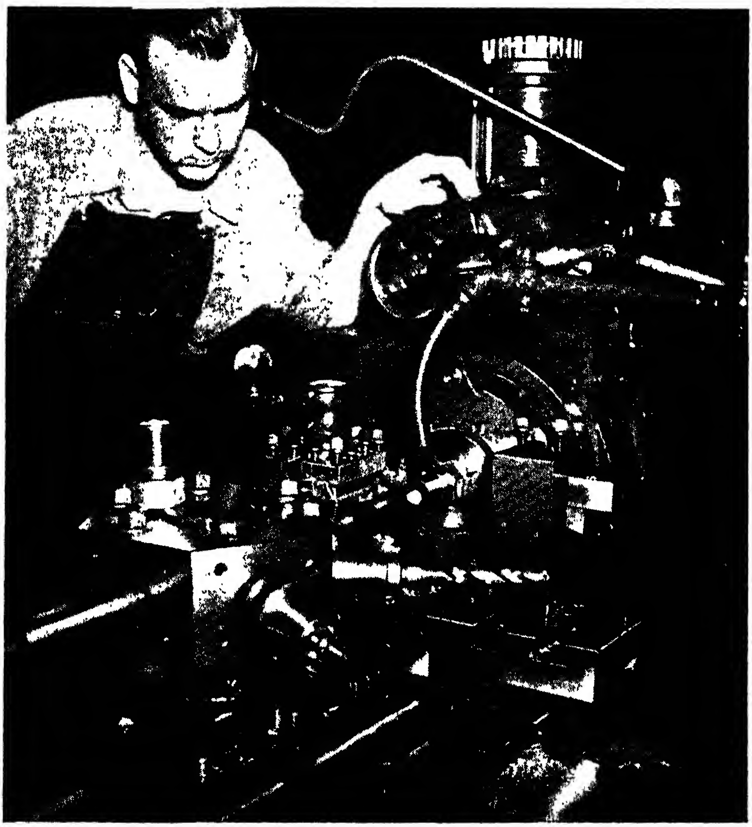

Fig. 2. Turret Lathe Tooled up for Machining Bulkhead Nipples from Hexagonal Bar Stock

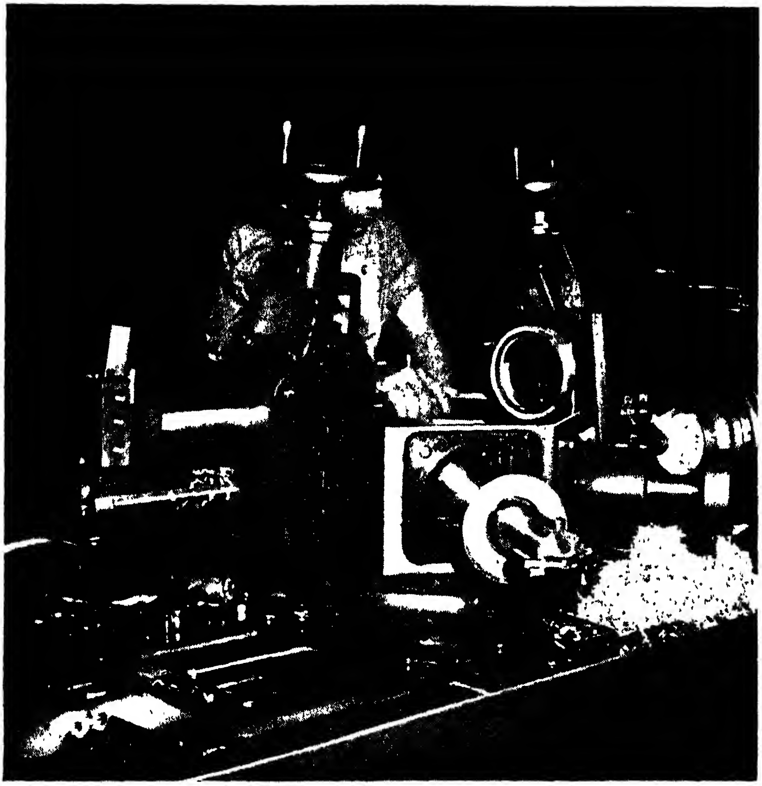

Fig. 3. Tooling Provided on Turret Lathe that Produces Packing Gland Nuts from Solid Duralumin Bars

A parting tool on the front of the cross-slide next cuts through the stock to within 0.010 inch of its center at the required distance from the front end to give the desired width to the finished piece. A slide tool on the fifth turret face cuts a recess near the back end of the large-diameter bore to provide clearance for a subsequent threading operation. The outside surface of the piece is next turned with a cutter on the front toolpost, and other cutters on the toolpost are used to round the front and back corners of the piece. Finally, the parting cutter on the toolpost completes the cutting off of the piece.

The partial cutting off is performed ahead of the finishing cuts so as to relieve the bar of all strains set up in the heavy boring and turning. If the complete parting were done at the end of all other cuts, the finished piece would be badly distorted.

Turning Airplane Engine Gear Blanks.— Fig. 4 shows the application of a turret lathe for the roughing operations on airplane engine gear blanks. In these operations, limits of plus or minus 0.004 inch are customary. The gears are made from S A E 2515 steel, either forgings or bar stock. A typical roughing operation is illustrated. It consists of turning and facing the gear end of an impeller gear sleeve after the shank end has been machined. To avoid tool marks on the machined shank, a split bushing is slipped over the shank and is gripped by the chuck jaws.

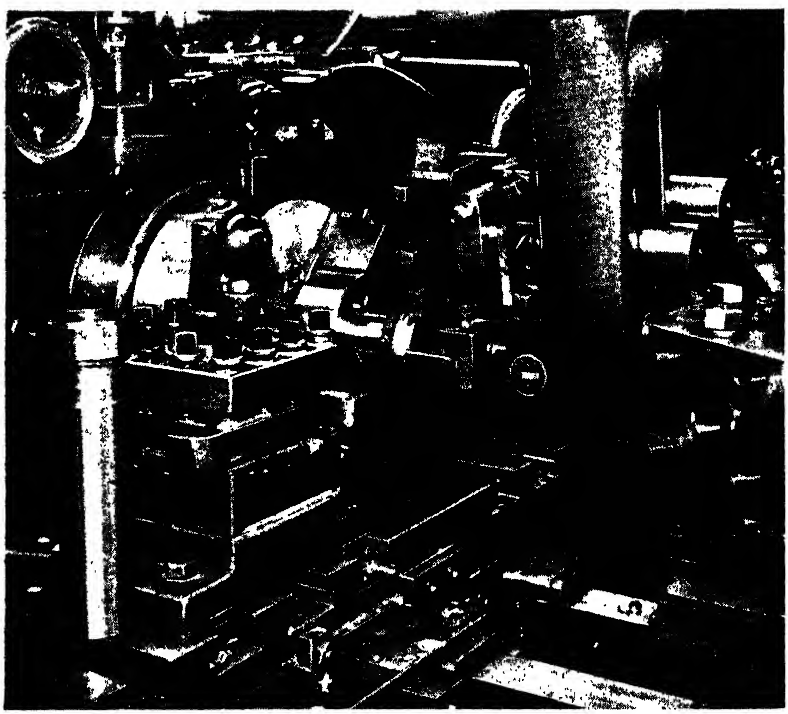

Fig. 4. Rough-turning the Upset End of an Impeller Gear Sleeve in a Turret Lathe, Three Cuts being Taken Simultaneously

At the time that this photograph was taken, three tools on the turret were turning the upset head of the forging, each tool cutting to a depth of about 1/8 inch. The tool-head is supported firmly by an overhead pilot-bar which enters the headstock. Tools on the square turret are used for facing the upset head and turning shoulders in front and back of the head, as well as turning a recess about 1 1/4 inches long, as seen on the part that stands at the front of the cross-slide. The long shank on this part is turned by a tool on the square turret in the previous operation referred to. Tungsten-carbide tools are used in both of these operations.

Indexing Fixture on Turret Lathe Headstock.—In Fig. 5 is shown a turret lathe used for machining the two gear chambers of pump bodies. The headstock is provided with

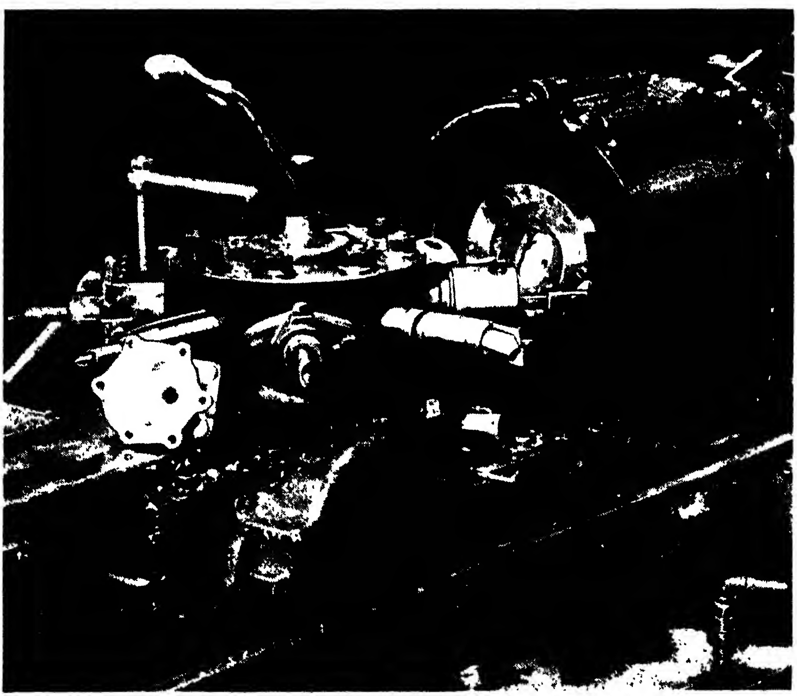

Fig. 5. Turret Lathe Machining Two Gear Chambers of Pump Bodies

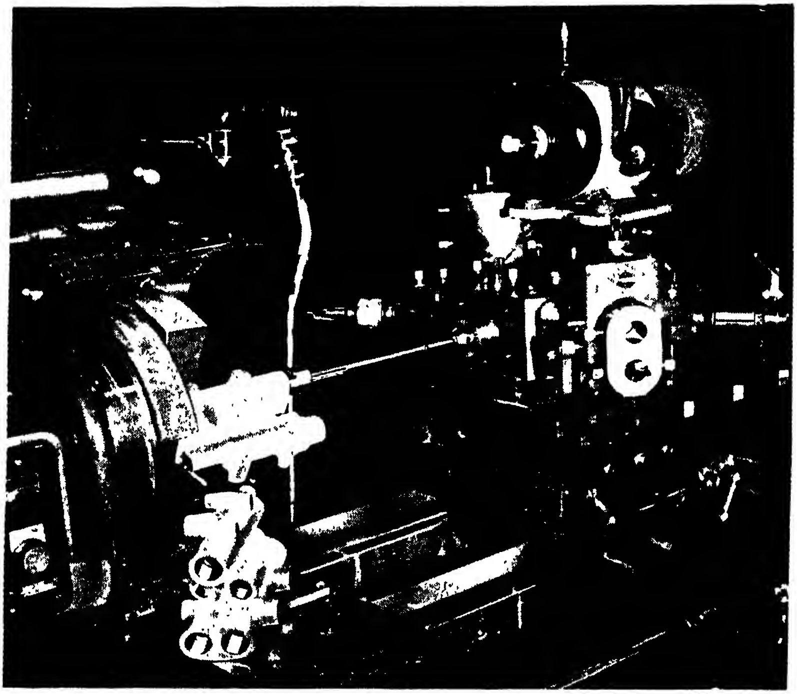

Fig. 6. Turret Lathe Tooled up for Machining Hydraulic Selector Valve Castings

an indexing fixture of eccentric design that enables the work to be shifted horizontally an amount equal to the center-to-center distance between the gear chambers as the work is turned through 180 degrees. An air cylinder locks the two members of the chuck together in the indexed positions.

Ten turret tools are required for this operation, the shaft and stud holes in the centers of the gear chambers being of different diameters, and one shaft hole being bored completely through, while the other hole is blind. The through shaft hole is first drilled, bored, and chamfered, after which the gear chamber is counterbored. Then the blind hole and the second gear chamber are similarly machined.

In this operation, the shaft holes, 0.5625 inch in diameter, must be machined to the specified size within plus or minus

0.0005 inch. The gear chamber must be 1.500 inches in diameter within plus or minus 0.001 inch, and the depth must be 0.500 inch within the same tolerance. The center-to-center distance between the chambers must be 1.174 inches, also within plus or minus 0.001 inch.

Turret with Special Motor Drive for Drill Spindle.—The turret lathe operation shown in Fig. 6 consists of machining two holes, 6 inches long, in hydraulic selector valve castings of duralumin. A fixture is used on the headstock, which is equipped with a slide that enables the work to be shifted radially after one hole has been completed, so as to bring the second hole in alignment with the headstock spindle. Drilling, reaming, boring, counterboring, and tapping cuts are taken on each hole, all with tools mounted on the turret. The 6-inch long holes must be machined to a nominal diameter of 0.500 inch within plus 0.0005 inch minus nothing. The drill spindle is driven by a separate motor, mounted on the turret, at a speed of about 400 R.P.M. This combination of revolving the work and the drill produces a smooth straight hole.

Use of Center in Turret for Supporting Outer End of Part During Turning Operation.— Some interesting operations are involved in machining airplane wing terminals. The forged S A E 4340 steel blanks come into the shop weighing around 24 pounds, and by the time they have undergone a dozen machine operations, their weight has been reduced about half. The first operation consists of turning three or four steps on the shank end of the terminal, as shown in Fig. 7, where rough and machined terminals may be seen resting on the turret of the lathe employed for this operation.

The rough square end of the wing terminals is gripped in the chuck of the turret lathe by tightening a series of adjustable screws. A center drill mounted on one of the turret faces is then advanced for centering the overhanging end of the shank, after which the turret is indexed to bring a ball-bearing center into line with the work, as illustrated, for supporting the shank end during the turning cuts.

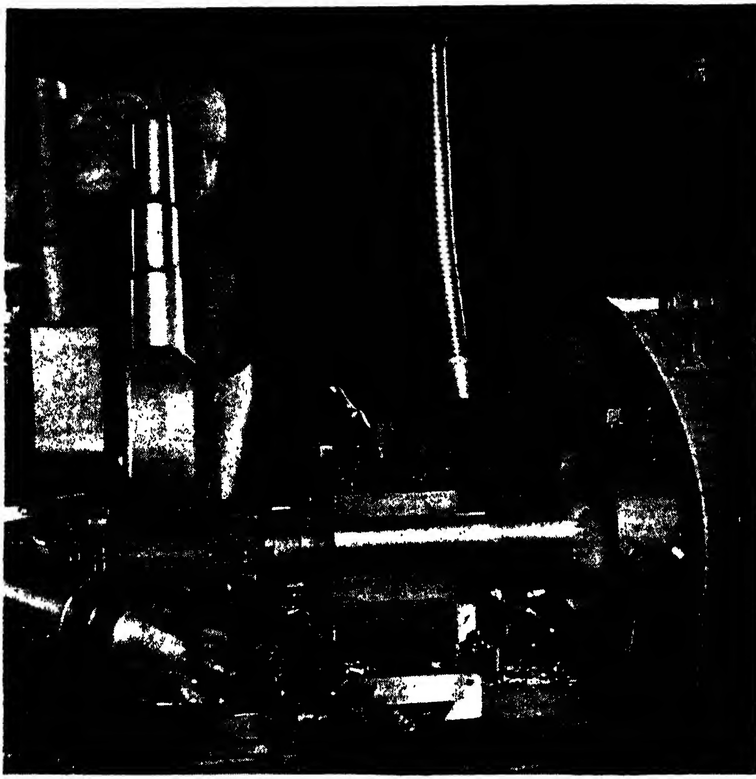

Fig. 7. Rough-turning the Shank End of Wing Terminal Forgings

Firthite tools on the square turret are used in taking the turning cuts, stock being removed to a depth of about 5/64 inch on a side. There are two tools, one for turning the three shank steps, and one for chamfering the front end of the square portion that is gripped in the chuck. The wing terminals are next drilled and bored in another turret lathe.

Machining Hydraulic Cylinders for Airplane Tail-wheel Struts.—Operating cylinders for hydraulic tail-wheel struts are machined from chromium-molybdenum steel tubing on the turret lathe shown in Fig. 8. One of the finished pieces is seen lying on the cross-slide. The tubing is turned the full length for the part being produced by a tool on the

front of the cross-slide which is moved in and out by the operator as required to obtain four surfaces of three different diameters. During the turning and while some of the following cuts are taken, the tube is supported on the overhanging end by a ball-bearing center on the hexagonal turret as shown.

When the turning cuts have been finished, threads are cut on the two large-diameter surfaces of the part by means of a chaser mounted on the toolpost at the front of the cross-slide. These threads are cut to a diameter of 1 1/4 inches, eighteen per inch, Class 3 fit. Upon the completion of the turning and threading, the tube is drilled out the full length necessary for one part by applying the long drill seen on the turret. Then the hole is bored to

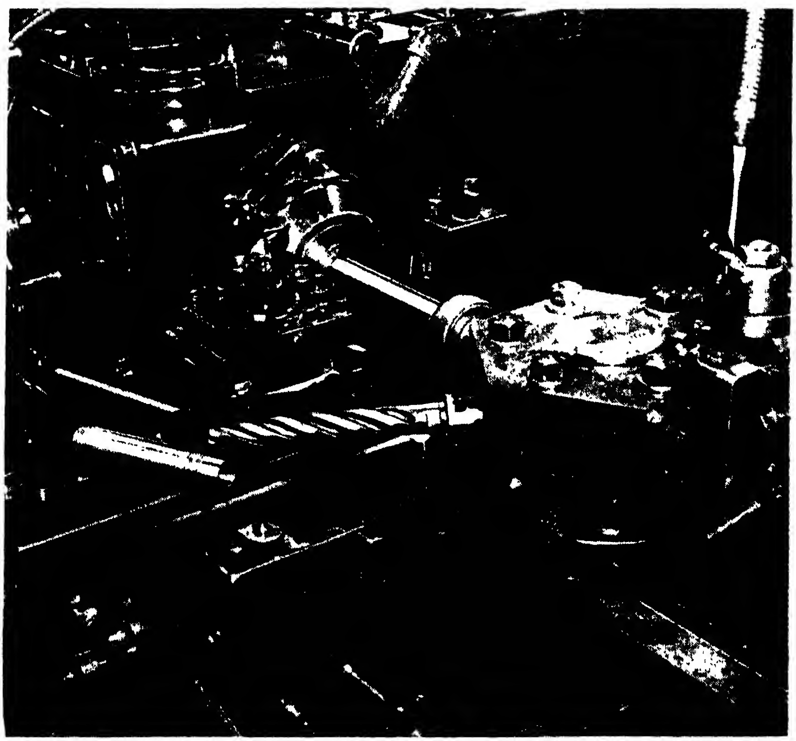

Fig. 8. Turret Lathe that Produces Hydraulic Cylinders from Chromium-molybdenum Steel Tubing

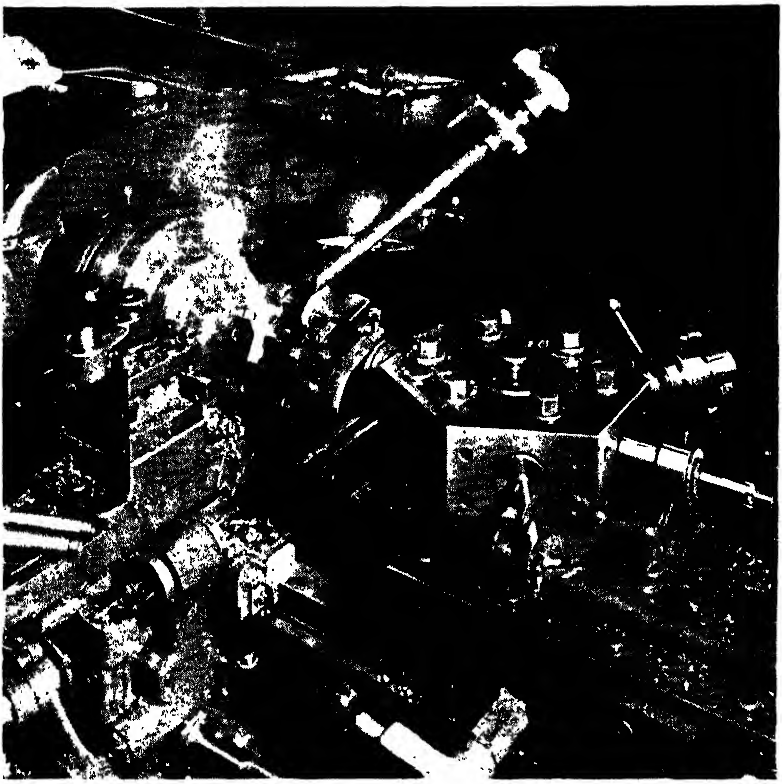

Fig. 9. Producing Machine Gun Screws in Turret Lathe

1 inch, within limits of plus 0.002 inch minus nothing, by means of a single-point tool that is also mounted on the turret. The finished part is severed from the stock by means of the cutting-off tool at the back of the cross-slide.

Operations on Machine Gun Screws.— Certain screws for a light machine gun are produced from bar stock on the turret lathe shown in Fig. 9. In this operation, the stock is first fed to a stop on the hexagon turret. Then the stock is rough-turned and centered by tools on the multiple-cutter turner seen in the operating position. Two tool bits on this attachment turn the bar for a length of approximately 3 3/16 inches. The fourth face of the turret is then indexed into position for drilling a hole of 0.500 inch

diameter for a length of approximately 3 inches. At the same time a tool on the front of the cross-slide turns the end of the bar to a thread diameter.

After the hexagon turret has again been indexed, a spot-facing tool machines the work to length. At the same time, the square turret on the cross-slide is indexed to bring two cutters into position for turning shoulders on the end of the work nearest the chuck. The die-head on the sixth face of the turret next cuts a short thread on the front end of the piece, and while this cut is in progress, a tool on the square turret turns a clearance back of the thread to almost the head end of the piece. Finally, the part is cut off by a tool on the back of the cross-slide.

Machining Cylinder Barrels for Tank Engines.—The turret lathe shown in Fig. 10 performs the first operation on

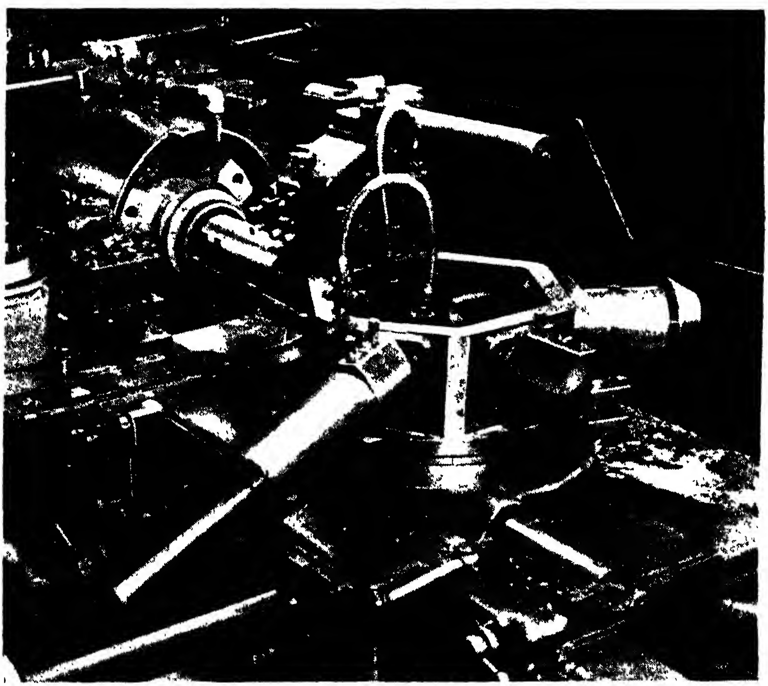

Fig. 10. Turret Lathe Employed for Facing, Turning, and Boring Operations on Cylinder Barrels for Army Tank Engines

the cylinder barrels of Army tank engines. During the first step in the operation, the front of the flange is rough-faced by a tool at the back of the cross-slide. Then two tools at the front of the cross-slide turn the hub and the flange rim. At the same time, tools mounted on a bar extending from one of the turret faces rough-bore the barrel, under-cut for a chamfer at the front end of the barrel, and face the hub to length.

The turret is then indexed to bring a second boring-bar into line with the work, after which it is advanced for finish-boring the barrel and turning the chamfer. While these cuts are in progress, two cutters on the square turret, the latter having also been indexed, finish-turn the hub and the flange. Limits of plus or minus 0.001 inch must be maintained in turning the hub and plus or minus

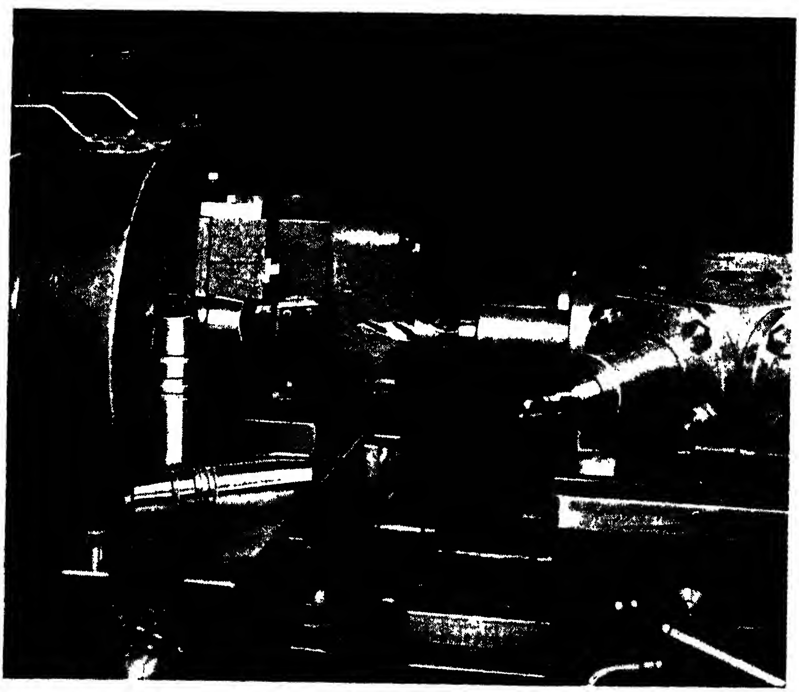

Fig. 11. One of a Battery of Turret Lathes Employed for Machining the Tracer-hole End in 40-millimeter Shells

0.002 inch in machining the bore. The nominal diameter of the bore is 5 1/8 inches, and the length 8 1/2 inches. Carboloy-tipped tools are used in this operation for a number of the cuts.

Form Tool Moved Sidewise by Auxiliary Cam.—Turret lathes equipped as shown in Fig. 11 are used to machine the tracer-hole end of 40-millimeter shells. The shell is held in a collet chuck. The first station of the turret is equipped with a two-step drill which cuts a hole through the tracer-hole end of the shell to meet the hole produced by an "automatic" in the opposite end. At the end of this drilling step, tools at the back of the cross-slide are advanced for facing the end of the shell and removing stock in the rifling band groove to produce a wavy annular ridge around the bottom of the groove. This wavy ridge is obtained by the sidewise movement of a form cutter on the cross-slide, which is ground with a small V-groove in the center of the cutting edge to suit the height and shape of the wavy ridge.

The sidewise movement of the form cutter is produced by a face cam on the headstock spindle, against which a roller on the form tool-slide is held in engagement by spring pressure. The oscillation of the tool-slide amounts to 1/8 inch, and is made three times for each revolution of the work, so as to produce three "wavers" around the shell. The purpose of this wavy annular ridge is to keep the rifling band that is later assembled in the groove, from turning on the shell when the shell is discharged from the gun.

A two-step reamer on the turret next finishes the hole drilled into the tracer-hole end of the shell accurately to size. Then the turret is indexed again to bring into position a solid tap which cuts left-hand Whitworth threads, 0.834 inch outside diameter, eighteen per inch, in the tracer hole. This step completes the turret lathe operations. Two identical sets of tools are provided on the turret, so that it is not necessary to index the turret through three idle stations each time a new operation is started.

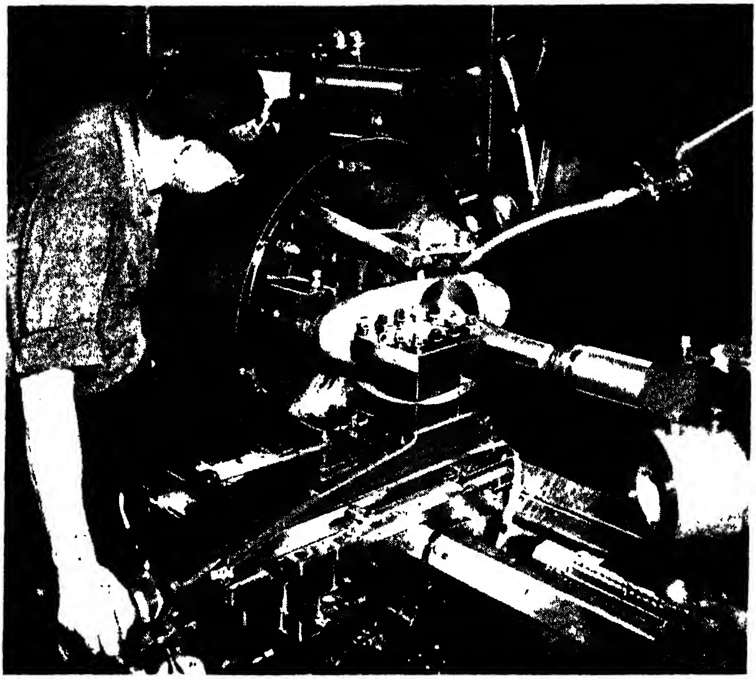

Fig. 12. Turret Lathe in which Straight and Taper Sections are Turned on the Spindle of Bogie Fulcrum Forgings, and a large Diameter Faced

Forging Supported by Headstock Fixture and Tailstock Center.—In Fig. 12 is shown a turret lathe equipped for machining the spindle of bogie fulcrum forgings of Army tanks. This spindle extends from one side of the forging, which also has two stub axles projecting from the opposite side. In the illustration, the main portion of the forging has just been faced with a tool on the square turret of the carriage preparatory to recessing this face and turning the spindle. Two straight diameters are next turned on the front end of the spindle, then a taper 7 1/4 inches long and a straight section adjoining the recess are machined. The taper cut is controlled by an attachment at the front of the turret lathe bed. The heavy end of the forging is held in a box type fixture on the machine headstock, and

the overhanging end of the spindle is supported by a ball-bearing center on the tailstock.

Machining Bearing Collars from Bars of Chromium-molybdenum Steel.—The turret lathe operation illustrated in Fig. 13 consists of producing bearing collars from bars of chromium-molybdenum steel, 3 1/8 inches outside diameter. The bearing collars are 5 inches long when finished, and are machined by the turret lathe to two internal diameters.

A tool on the first face of the turret center-drills the end of the bar, while the second turret face is provided with a drill for producing the smaller hole the full length of the part. The third turret face is equipped with a drill for producing the larger diameter bore that extends about half way through the piece, while the fourth turret face is pro-

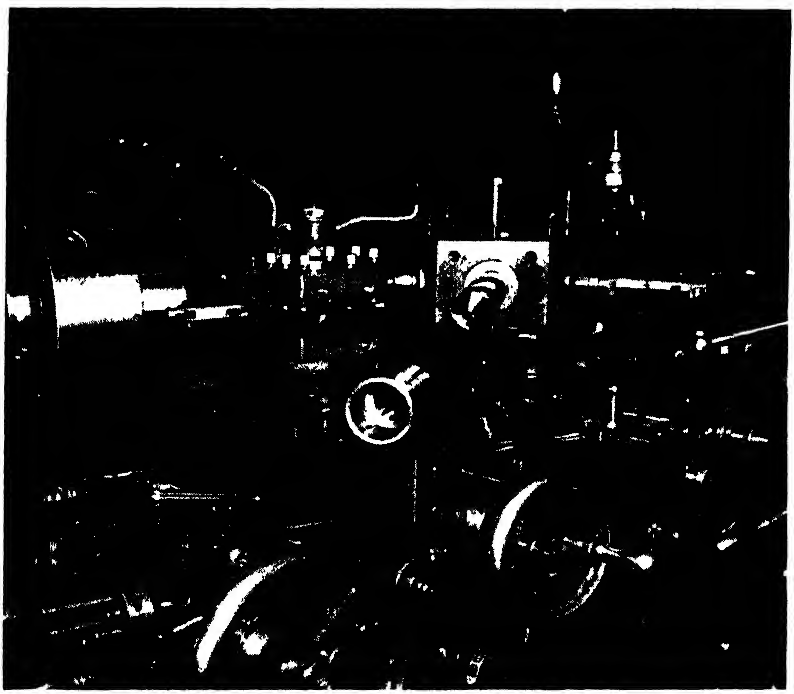

Fig. 13. Tooling for Producing Bearing Collars from Solid Bars of Chromium-molybdenum Steel

vided with a boring tool for the small hole, and the fifth turret face with a boring tool for the large hole. Tools on the square turret of the cross-slide take facing and chamfering cuts. Turning cuts are taken on this part in another machine after additional pieces have been welded to the inside.

Turning Brass Fuse Heads on Electrically-controlled Turret Lathe.—Fig. 14 illustrates a second operation on brass fuse heads, which have previously been machined on a 1-inch automatic. The machine used for this second operation is an "electric turret lathe." The fuse head is loaded into the collet chuck, and then successively rough-drilled through a central rib by means of a No. 44 drill, rough-reamed, faced and burred, finish-reamed in the long hole, and finally finish-reamed in a short counterbore. This

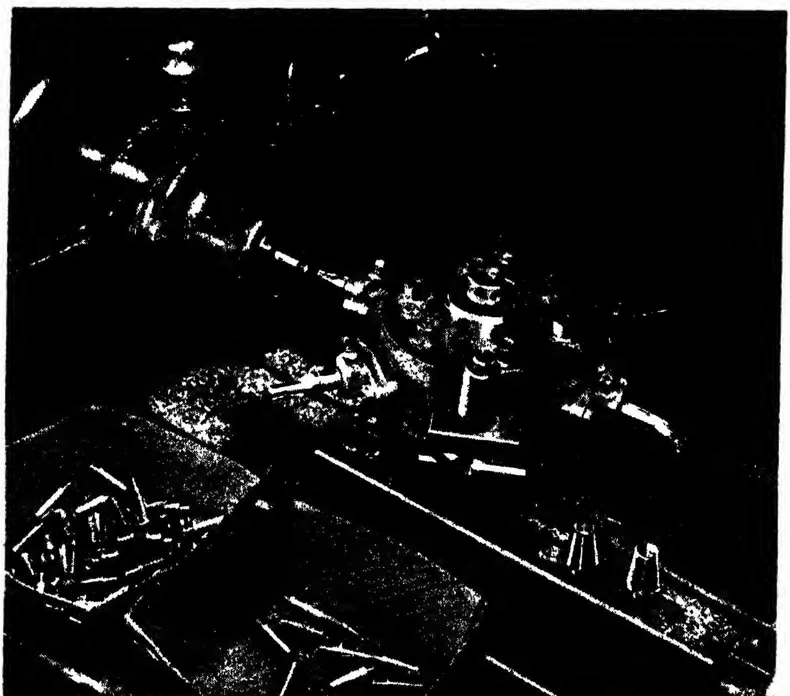

Fig. 14. Machining Fuse Heads on an Electric Turret Lathe

operation is also performed on a 1-inch automatic with magazine feed.

The production rate on the electric turret lathe is 1200 per 8-hour day. With this electric type, speed changes, reversal of the spindle, instantaneous application and release of the brake, actuation of the bar feed, and operation of the automatic chuck are all effected electrically. While this completely electrically controlled turret lathe was designed primarily for brass work, it is also applicable to other work that can be machined at high speed.

Operations on Gas Retainers for Machine Guns.—In Fig. 15 is shown a turret lathe that produces gas retainers for the caliber 0.50 machine guns from 3 1 6-inch diameter bars of stainless steel. When these parts leave the machine their wall is only 3 32 inch thick for a depth of approximately 7 inches.

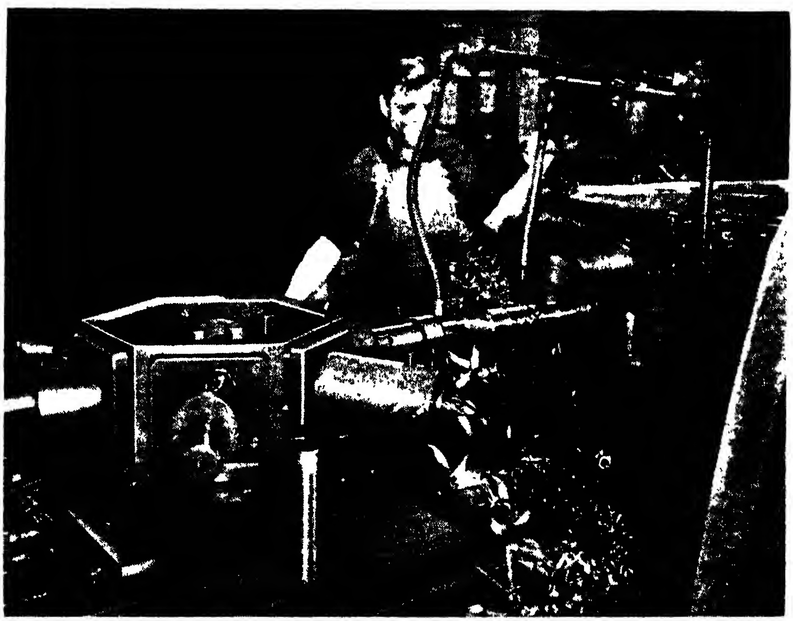

Fig. 15. Turret Lathe for Making Gas Retainers from 3-inch Steel Bars

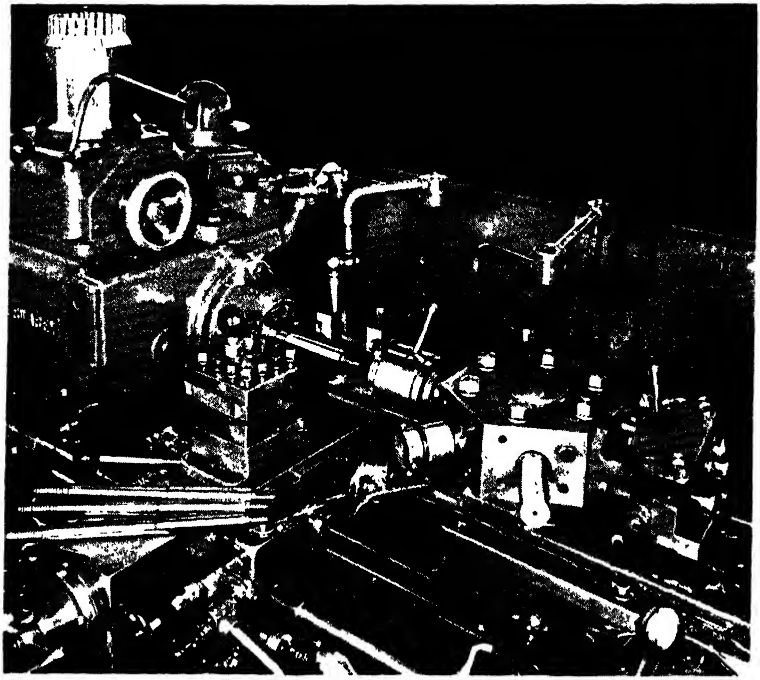

Fig. 16. Threaded Shafts for Anti-aircraft Guns are Produced from Hard Manganese Bar Stock in Turret Lathe Shown

In this operation the turret tools are used in the following sequence: Center-drill the end of the bar; drill a 2-inch hole to a depth of 7 inches; drill a 2 5/8-inch hole to about the same depth; bore the hole and form the inner end to a rounded contour; finish-bore the same surface; and, finally, counterbore the open end for a thread. During these cuts, tools on the square turret at the front of the machine take various turning and facing cuts on external surfaces and also cut the finished part from the bar. A finished part is seen in the foreground.

Use of Two Dies to Insure Accurate Threading of Tough Material.—The turret lathe shown in Fig. 16 is employed for producing shafts for anti-aircraft guns from hard manganese bar stock. These shafts are 13 3/8 inches long

over all, and have a maximum diameter of 1 inch which must be maintained within plus 0.000, minus 0.001 inch as the pieces come from the machine. A 7/8-inch thread, 14 per inch, NF-2, is cut on one end, and a 1/2-inch thread, 20 per inch, NF-3, on the other end. In this operation, the stock is first fed to the turret stop, after which a roller-supported turning tool on the turret turns the overhanging end. The next turret tool centers the end of the bar, and then, while a center on the turret supports this end, the remaining length is turned by a tool on the front toolpost.

A Geometric die-head on the next station of the turret then cuts the thread, after which a button die on the turret is traversed over the thread in case the latter is over size, which sometimes happens because of the material being unusually tough. Two tools on the back toolpost face the shoulders of the large-diameter portion to length just before the piece is cut off. The opposite end of these shafts is machined in the same turret lathe with a slight modification in the tooling.

Finish Boring Airplane Propeller Shafts.—The finish-boring of airplane engine propeller shafts is illustrated in Fig. 17. The propeller shaft comes to the turret lathe rough-turned and with a hole drilled the full length. The shaft is chucked on the outside at one end, and is supported in a hinged type of steadyrest at the outer end.

Tools on the square toolpost on the carriage face and chamfer the outer end of the propeller shaft and rough-bore it to two diameters, while six piloted boring-bars on the turret rough- and finish-bore the work to four diameters, and form three tapers and two radii. Two additional tools on the turret ream straight and tapered surfaces. All of the boring-bars and the reamers are drilled to provide for the delivery of coolant to the cutting edges of the tools.

This machine is equipped with a three-jaw scroll chuck and has a bed extension of 24 inches. Feeds from 0.009 to 0.015 inch are employed in machining this steel forging, while the cutting speeds range from 60 to 100 surface feet per minute. The floor-to-floor time for the operation is 45 minutes.

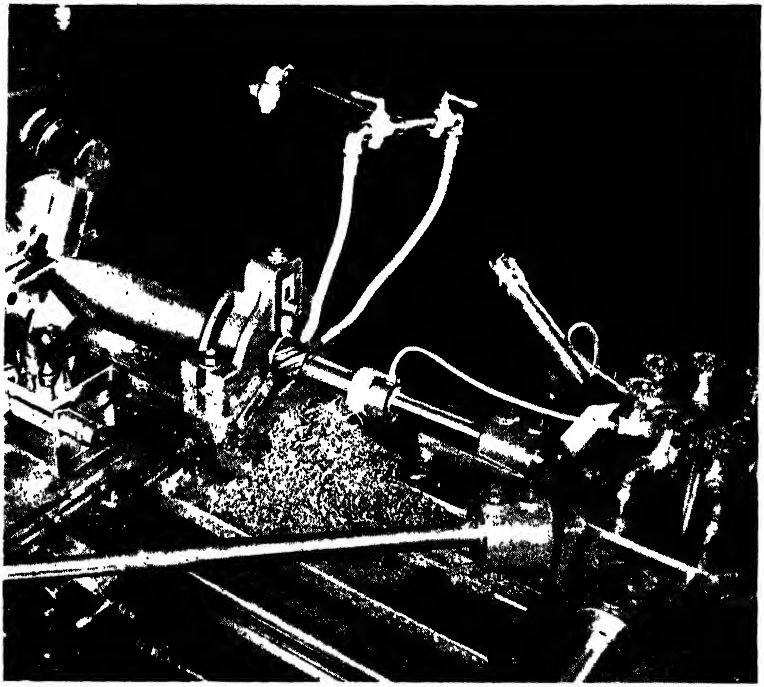

Fig. 17. Finishing Steel Forged Propeller Shafts

Machining Bearing Shell on Vertical Turret Lathe.—The job shown in Fig. 18 consists of machining the inside of a spring bearing shell on a vertical turret lathe. Various surfaces are bored to one diameter in this operation, and then a series of internal dovetail grooves are cut into the board surfaces to receive babbitt. All these cuts are taken with tools mounted on the turret. The iron casting measures approximately 19 inches in the bore, and is 30 inches long. The finished surfaces on the outside of the casting were turned by tools on the side-head.

It will be noted that this machine was referred to as a "vertical turret lathe." A large percentage of the turret lathes in use are of the horizontal type, like the designs previously referred to in this chapter. Machines which are called *vertical turret lathes* by one manufacturer may be classed as *side-head boring mills* by another manufac-

turer, owing to the fact that they are designed along the lines of a vertical boring mill with the addition of a side-head; therefore, the name vertical turret lathe is not one that is always applied to this type of machine, although such a design may properly be classified as a vertical turret lathe, as it possesses the same general features as a horizontal machine designed for chuck work. When a machine is simply referred to as a "turret lathe," this is generally understood to be a horizontal machine.

Turning Army Tank Turret Rings on Vertical Turret Lathe.—The machining of turret rings for Army tanks re-

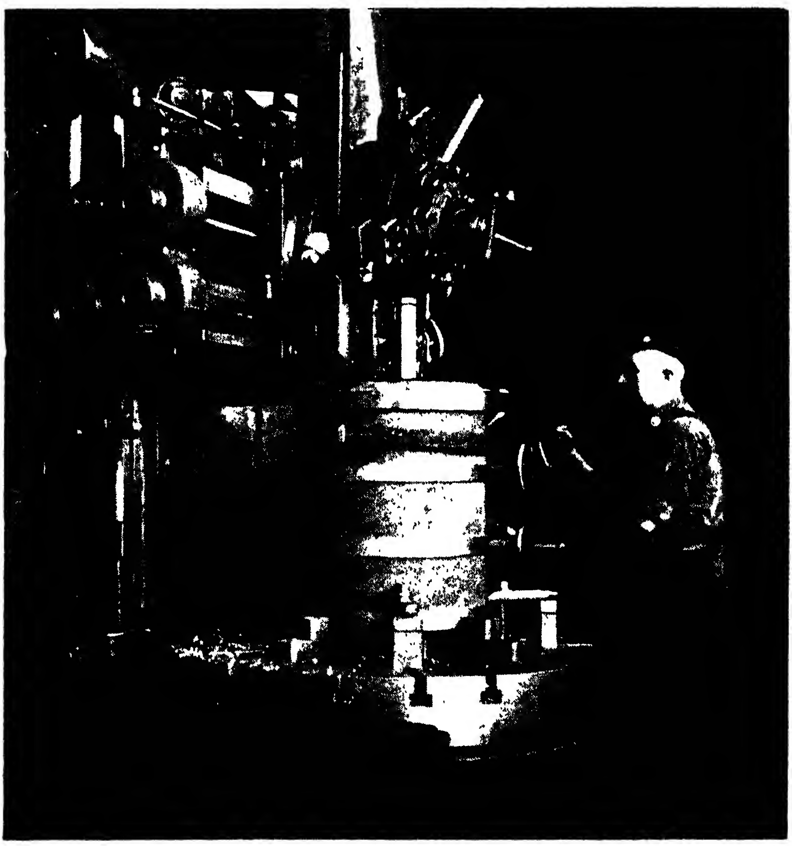

Fig. 18. Example of Work on Vertical Turret Lathe

quires a high grade of workmanship. Fig. 19 shows such an operation being performed on a vertical turret lathe. These parts are made from steel forgings having a comparatively large nickel content. Tools on both the turret and ram are used, a total of thirteen cutters being required for the various turning and facing cuts taken on that side of the ring that is uppermost in the illustration. Most of the turret stations on this machine are provided with tools for taking two cuts simultaneously, the only exception being in the case of one station that is equipped with a tool having a cutting edge formed to the shape of a large fillet.

Fig. 19. Machining Turret Rings for Army Tanks with Vertical Turret Lathe

The ram is provided with two cutters which simultaneously face two surfaces to the requirements of a "Go" and "Not Go" step type of gage. Rings of seven different diameters, some larger and some smaller than the one illustrated, are required on each tank.

Advantages in Using Standard Turret Lathe Tools as far as Possible.—While special tools must be used for many turret lathe operations, standard tool equipment should be utilized whenever practicable. Special tools, as the name indicates, are usually not very flexible. Designed for one particular job, they generally have to be taken off the machine when that job is completed and replaced by others for succeeding work. Modern standard tools, on the other hand, have been designed to do several different types of work.

Probably the leader in the development of such widely universal standard tooling is the turret lathe industry. Turret lathe builders have found, over a long period of time, that most jobs can be done with a relatively small number of tools; and in the last few years they have developed these tools and the technique of utilizing them efficiently to a point that far surpasses anything known heretofore. These universal tools are the result of many suggestions made by customers, operators, and manufacturers' service men in the field, as well as home office engineers. Many of them originated as a special tool, designed to do a job no standard tool could do, but because of its original success, it was improved and made available to other users.

Two sets of tools have been standardized by a prominent turret lathe manufacturer—one set for bar work and one for chuck work. In a large shop, each machine is equipped with either one set or the other—it is never necessary to have both. This, of course, is because, in most cases, machines are assigned to either one type of work exclusively or the other. In small shops or departments, however, both bar and chucking equipment are usually necessary for each machine.

Automatic Machines which Turn Parts from Bar Stock

The machines in this section all belong to the lathe family, but they are not called lathes. They may be known either as "automatic screw machines" or merely as "automatics." Trade names are also used in certain cases. Some of these machines have a single work-holding spindle so that one bar of stock is operated on at a time. Other machines, as will be shown by examples to follow, have several spindles so that an equal number of bars can be machined simultaneously.

These single- and multiple-spindle machines are fully automatic; thus, after completing the operations on a part and severing it from the bar, the latter moves forward to present enough of its length to the tools for making another piece. This cycle is repeated until the bar (or bars, in the case of a multiple-spindle machine) must be replaced. Many machine tools which are classed as "automatic" are not capable of repeating a cycle of operations in producing duplicate parts. In other words, an operator must replace the finished part with a rough one at the completion of each cycle of machining operations.

Operations on an Hydraulically-operated Single-spindle Machine.—A single-spindle screw machine tooled up for producing a fuel-tank stand-pipe assembly from brass bar stock is shown in Fig. 1. One of the finished pieces of work is seen at the left of the front cross-slide. In this operation, the stock is first fed forward to a stop on the tool turret. Then a box-tool in the second turret station turns the stock for a length of 3 3/8 inches and also centers, counterbores, faces, and chamfers the end of the stock.

The photograph was taken immediately after the tools which take these multiple cuts had been indexed from the working position. The third turret station is equipped with a tool that drills a 7/8-inch hole to a depth of 2 1/4 inches. The fourth station is provided with another drill of the same diameter that cuts the hole to a depth of 3 3/4 inches.

While the drilling steps are in progress, a tool on the front cross-slide forms a surface near the left or head end of the piece ready for threading, after which another form tool on the rear cross-slide reduces the extreme left-hand end of the piece to a diameter of 1 3/16 inches for a width of 3/8 inch. Threads are next cut to a diameter of

Fig. 1. Single-spindle Screw Machine Tooled for Producing Fuel-tank Stand-pipes from Brass Stock

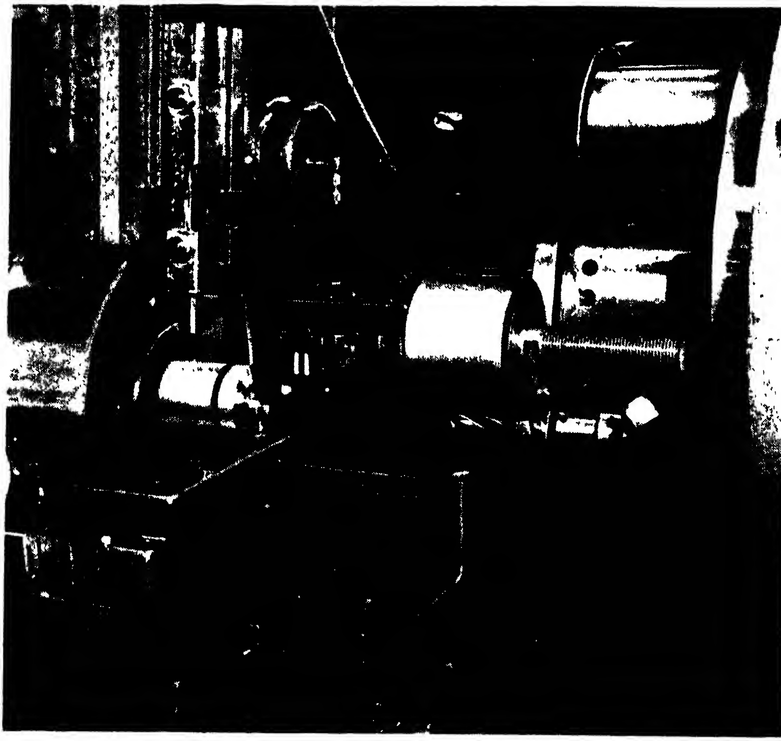

Fig. 2. Single-spindle Automatic Tooled for Producing Four Washers at Each Machine Cycle

1 1/4 inches, eighteen per inch, on the surface previously mentioned for a length of 5/8 inch. This is done by a die-head in the fifth station of the tool turret. The part is finally cut off by a tool mounted above the work-spindle. All movements of the machine are actuated hydraulically.

Producing Four Washers Simultaneously.—Washers for absorbing engine-mount vibration are machined four at a time by the 3 3/4-inch automatic illustrated in Fig. 2. The washers are produced from 2 1/8-inch diameter bars of aluminum alloy. Two tools are mounted at the front of the cross-slide, one a form cutter and the other a cutting-off tool. There are two cutting-off tools at the rear of the cross-slide and another on an overhead slide that is in line with the center of the machine spindle.

In an operation, the stock is first fed forward against a stop on the tool turret, and then while the forming and cutting-off tools are in action, a 7/16-inch drill in the second station of the tool turret drills part way through the portion of the bar stock that is being machined into four washers. At the same time, facing cutters in the same station of the tool turret machine the front end of the bar to a slight angle. A drill in the third station completes the drilling of the 7/16-inch hole through the portion of the stock that is being machined. At the time that the photograph was taken, the tools on the front of the cross-slide had performed their function and the first drilling step had been completed.

Machining Brass Detonator Holders on Single-spindle Machine.—The automatic shown in Fig. 3 is tooled up for producing detonator holders from 3/4-inch diameter brass bars. Finished pieces are seen lying on the tray at the front of the machine. In this operation, a drill on the turret first drills a small-diameter hole in the end of the bar to a depth slightly greater than the length of the finished part. The next tool on the turret then counterbores the hole to almost the full depth of the finished piece. The third station of the turret is equipped with a tool mounted on a slide that is fed sidewise after the tool has been fed into the counterbored hole, for under-cutting a recess at the inner end of the counterbore. The fourth turret tool is a self-opening die-head, which threads the end of the bar for a length equivalent to that of the finished piece. The fifth turret tool is a solid tap that cuts threads in the counterbored hole.

Next, the cross-slide is fed toward the rear to bring a form tool at the front of the cross-slide into contact with the work for chamfering the front end, and to start cutting off the bar stock to a vee, so as to produce a chamfer at the back end of the piece also. The cross-slide is then fed forward to bring into action a cutting-off tool mounted at the rear of the cross-slide. The swinging stop that controls the advance of the stock is shown in the downward position, ready for starting the production of a new piece.

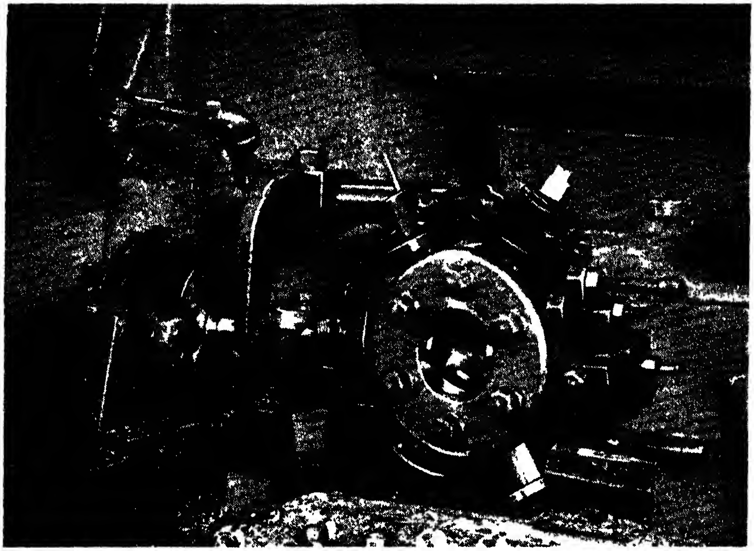

Fig. 3. Automatic Equipped for Producing Detonator Holders from Brass Bar Stock

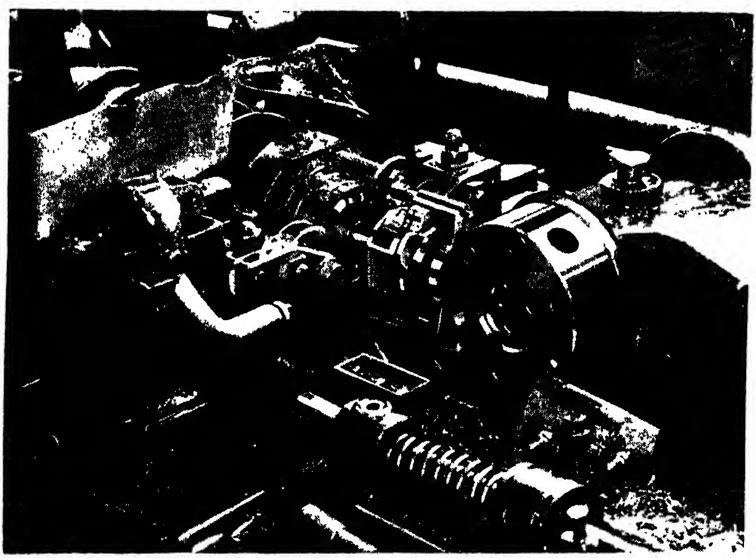

Fig. 4. Machining One Thousand Threaded Pieces an Hour on a Single-spindle Automatic Screw Machine

Threading One Thousand Screws Per Hour on Single-spindle Automatic.—Fig. 4 shows the threading of a small screw at a very rapid rate on an automatic screw machine, using insert-chaser die-heads. The piece being threaded is a No. 10-32 screw, 5/8 inch long. It is threaded for its entire length. The material is cold-rolled steel. The threading speed is 2750 revolutions per minute. The production is 1000 pieces per hour, and the number threaded before grinding the chasers varies from 50,000 to 100,000.

Machining Fuse Parts on Automatic Screw Machines.—Many fuse parts are turned out by automatic screw machines. Some of the pieces are as small as 1/16 inch in diameter and some are less than 1/16 inch long. Tolerances as close as 0.001 inch must be maintained. On a typical cup-shaped piece of stainless steel with an outside diameter of 0.190 inch and a wall thickness of only 0.015 inch, the limits on the outside diameter are plus 0.000, minus 0.002 inch, and the limits on the inside diameter, plus 0.001 inch, minus 0.000. The over-all length of the piece must be 0.457 inch within plus 0.000, minus 0.002 inch.

In Fig. 5 is shown a high-speed automatic screw machine producing fuse booster cups from 1 1/8-inch aluminum bar stock. These parts have a wall only 0.03 inch thick at the open end when finished, and the closed end is 0.057 inch thick. The length is approximately 15/16 inch. In this operation, the stock is fed to a stop in the first station of the turret, after which the turret is indexed successively for rough-drilling, cutting the external thread with a die-head, flat-bottom drilling, reaming, and turning a short length in front of the thread. The turning is done with a knee tool seen in the illustration indexed in line with the work. A tool on the front slide forms the piece during the first drilling step, and a tool on the rear slide cuts the part from the bar at the end of the operation. The threads are 1 1/8 inches in diameter, twenty per inch, NS-1. About 800 of these booster cups are produced per eight-hour day.

Producing Machine Gun Stabilizer Bodies on Single-spindle Automatic.— The automatic shown in Fig. 6 is

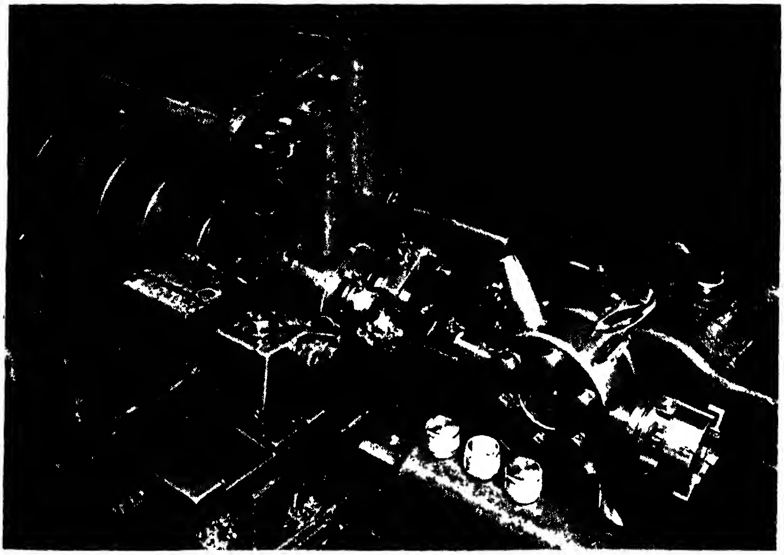

Fig. 5. Single-spindle Automatic Producing Aluminum Fuse Booster Cups with a Wall Thickness of Only 0.03 Inch

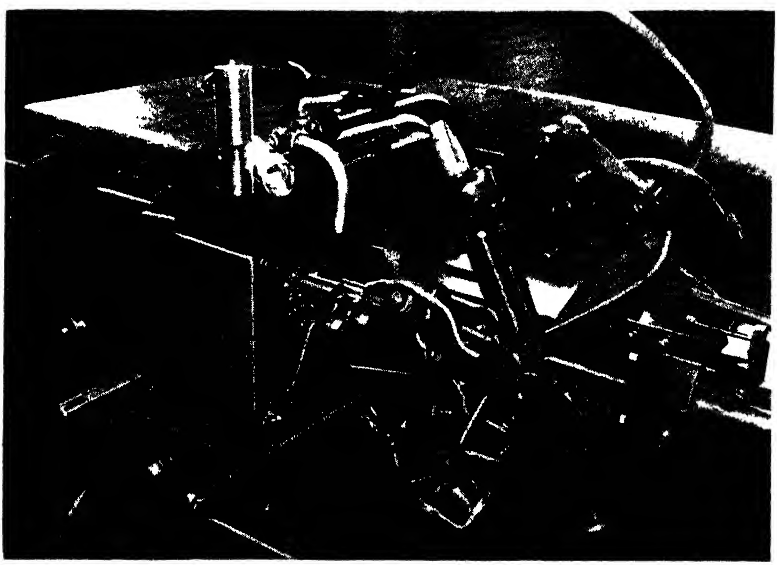

Fig. 6. An Automatic Tooled for Producing Machine Gun Stabilizer Bodies

tooled up for producing the stabilizer body of caliber 0.50 machine guns, from stainless-steel bar stock. Finished parts are seen on top of the headstock. The sequence of steps in this operation is as follows: Feed stock to turret stop; drill a 1 7/16-inch diameter hole and turn outside diameter with tools that are mounted on the same holder as the drill; drill a hole 13/32 inch in diameter and also finish-bore the larger hole to from 1.437 to 1.445 inches with tools on the same holder as the drill, the outside surface being recessed at the same time with a tool on the front slide; rough-form a rounded surface at the bottom of the large hole; cut a recess for an internal thread; and finish-form a radius at the bottom of the large hole, at the same time facing the end of the part with a tool on the same holder. At the end of these cuts the stock is fed forward to a second stop in order to obtain the desired length, after which the part is cut from the bar by means of the tool on the rear slide.

Examples of Work Done on a Four-spindle Automatic.— On the front slide of the Cleveland 2 5/8-inch automatic illustrated in Fig. 7 may be seen some typical examples of work turned out by this machine, which is a four-spindle automatic. This machine is shown tooled up for producing the small spool-like piece *A*, which is made from S A E 2340 steel at the rate of seventy seconds per piece. It is rough- and finish-formed from bar stock by form cutters on the two top slides, and drilled, reamed, and bored by tools on the main slide. A tolerance of 0.001 inch is specified on the hole diameter, and the width between two lands must be maintained within 0.002 inch. A particularly fine finish is required on the surfaces of the annular V-groove.

At *B* are shown domed pieces which are produced from steel bar stock in an average time of fifty-five seconds. The under side of the dome is counterbored in the machine to a thin wall, a tolerance of 0.002 inch being specified for this diameter. These parts are 2 1/2 inches maximum diameter. At *C* is shown a part approximately 1 1/2 inches in outside diameter which is machined out of steel bar stock to a circular and end wall thickness of 1/16 inch. In addi-

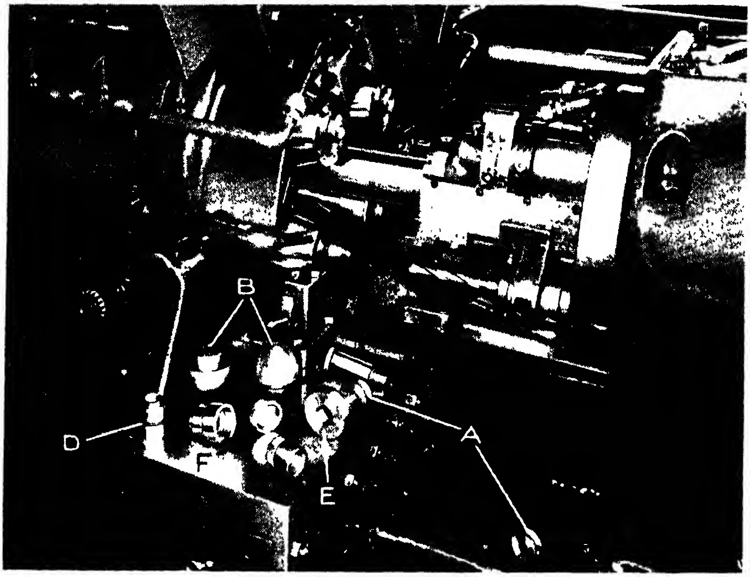

Fig. 7. Four-spindle Automatic and Examples of Work

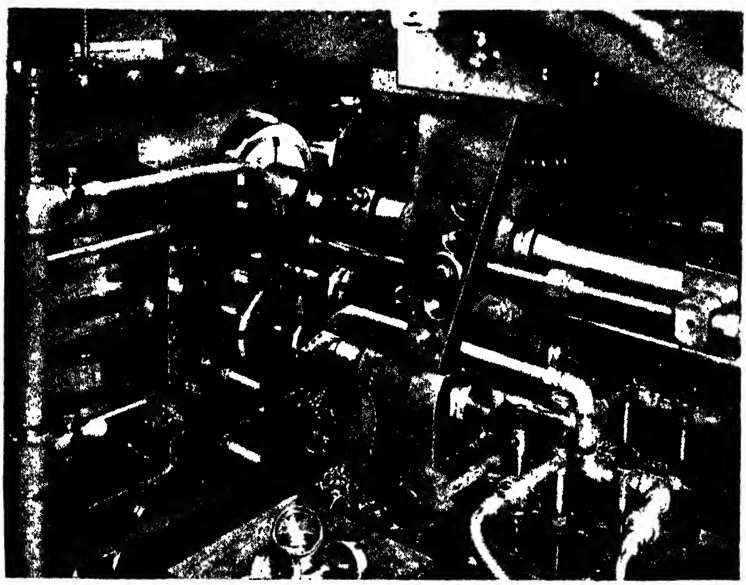

Fig. 8. Four-spindle Automatic Tooled for Production of Special Nuts

tion, an annular recess 0.032 inch deep must be cut around the inside surface, and the outside surface must be knurled for a short distance from one end. This piece is produced in twenty-six seconds.

The part shown at *D* is made from phosphor-bronze bar stock, being formed on the outside by tools on the top slides while drilling, tapping, and recessing operations are performed by tools on the main slide. At *E* is another piece made from phosphor-bronze, which is threaded on the outside, and at *F* a part made from the same material with a knurled surface.

Machining Special Nuts from Alloy Steel Tubing.—The 4 3/8-inch four-spindle machine illustrated in Fig. 8 is tooled up for producing intake pipe nuts from seamless alloy steel tubing. In this operation, the tubular piece is completely machined both inside and outside before being cut off. The tubular stock is fed forward to a swinging stop in the upper front station. Then, after being indexed to the lower front station, a tool on the main tool-slide bores the inside of the tube. In the second station at the lower rear, counterboring and chamfering cuts are taken by tools on the main slide, a tool on the rear cross-slide at the same time turning the outside of the tube the required length for one piece of work. In the top rear position, a form cutter on the rear cross-slide finishes the outside of the tube to the required contour, while a tool on the main slide chamfers the inside edge of the stock. Finally, in the top front position, the piece is cut off by a tool on the front cross-slide before the stop swings into its operative position. Normally, a sheet-metal chute extends from below the top front position to the receptacle at the front of the machine.

Machining Base Ends of Shells on Four-spindle Automatic.—Figs. 9 and 10 show the application of a four-spindle automatic of 3 1/2-inch size, for finish-machining the base ends of 3.7-inch shells, including the cutting of the rifling-band grooves and wavy annular ridges. At the start of this operation, the finish-turned shell is laid on a rest in

the lower position of the machine and slipped by hand part way into the chuck and over a centering bar that enters the shell cavity. Then a ram is automatically operated horizontally from the left-hand end of the machine to push the shell completely into the chuck. The shell is gripped securely by the chuck just before the spindle carrier indexes. In Fig. 9, a finished shell is seen lying on the rest, and the loading ram may be seen to the left of the shell.

In the lower front position of the automatic, which may be seen in Fig. 10, a form cutter mounted on the side slide

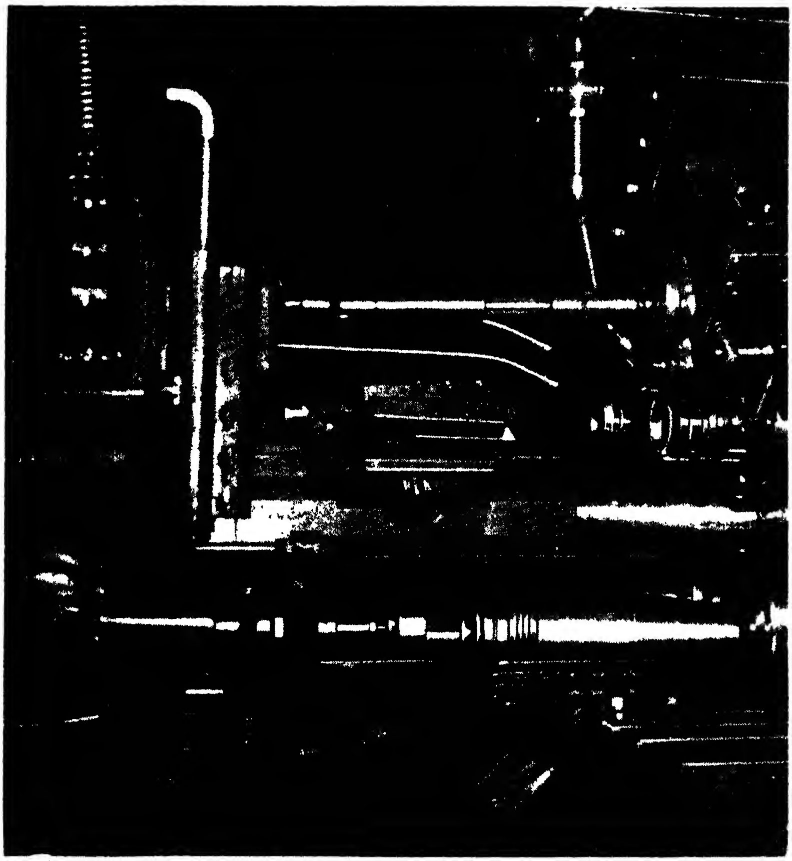

Fig. 9. Automatic Employed for Machining the Choke Groove, the Dovetail Rifling-band Groove with its Wavy Annular Ridges, and the Base Recess in 3.7-inch Shells

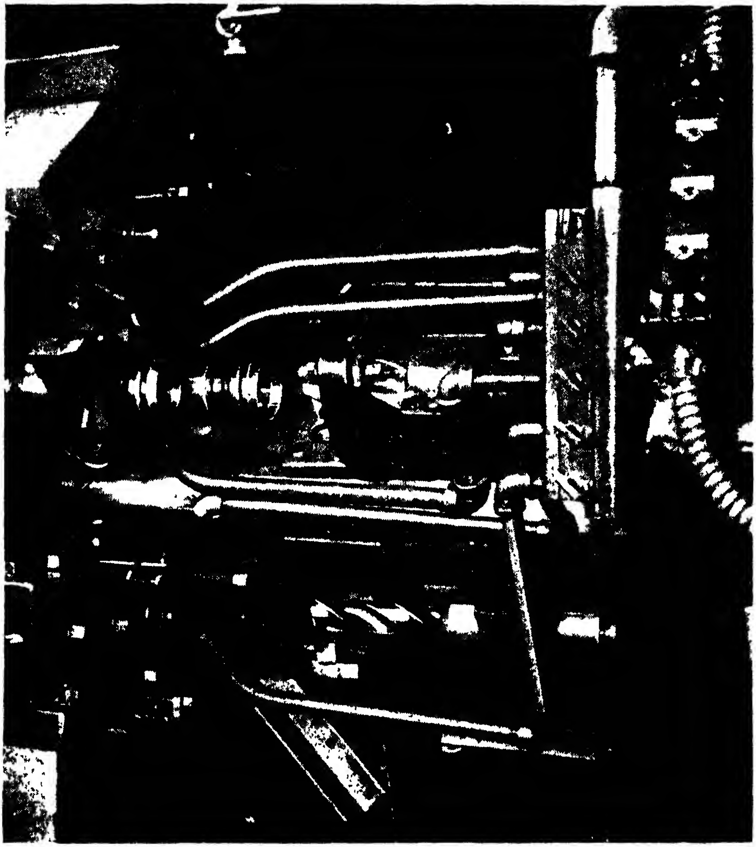

Fig. 10. Front View of Automatic Employed for Turning the Shell Grooves and Base Recess; Tooling in the First Two Working Stations is shown

turns a half-round choke groove around the shell near the base end and turns the groove for the copper rifling band to depth, ready for machining the wavy annular ridges and the dovetail under-cuts. While the turning operation is taking place, a 1 1/2-inch drill on the end tool-slide in the lower front position cuts away a boss on the base end of the shell and starts to form a recess. A form tool held on a knee-turner, also mounted on the end slide, rounds the corner of the shell and turns the crimping lip on the face.

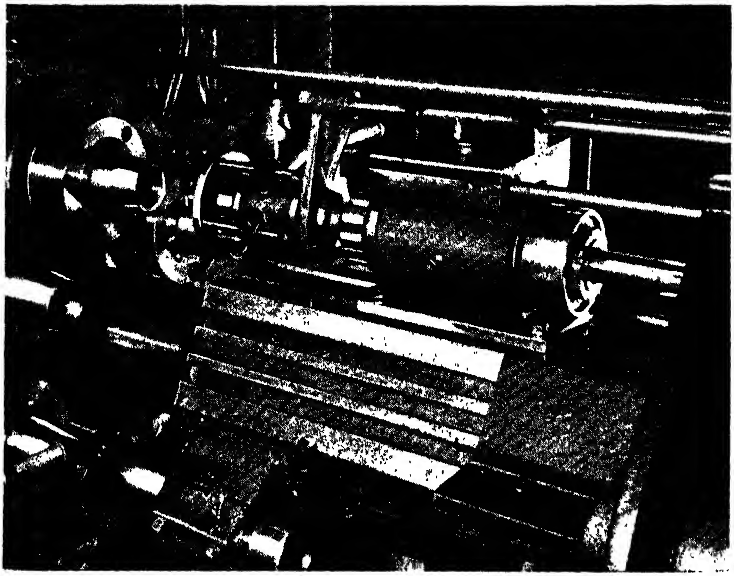

Fig. 11. Six-spindle Automatic Counterboring, Recessing, Threading and Chamfering Open Ends of the Shells

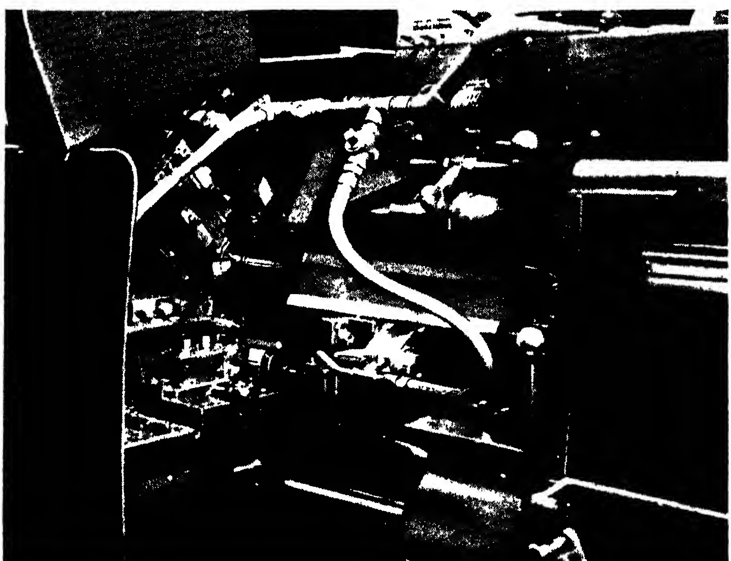

Fig. 12. Machining Bolts on Six-spindle Automatic

In the upper front position of the machine, Fig. 10, the side slide is equipped with a fixture that supports cutters on opposite sides of the shell and feeds these cutters downward into position and then successively sidewise in opposite directions to under-cut both sides of the groove so as to produce the dovetail shape. At the same time, a 3-inch drill on the end slide advances to machine the recess to its approximate diameter, and a cutter on a knee-turner mounted in the same position of the end slide finish-turns the rounded corner of the shell and the crimping lip as well.

The wavy annular ridges in the rifling-band groove are machined in the upper back position of the automatic, which, as shown in Fig. 9, is provided with a special tool fixture. This fixture is reciprocated sidewise three times during each revolution of the work, so that "waves" are machined by a form tool mounted on the fixture. Reciprocation of this tool is effected by the rotation of a small drum cam in the special fixture which is driven from the headstock of the machine.

While the wavy annular ridges are being turned, the recess in the base end of the shell is bored to the finished dimensions by a single-point tool mounted on the end slide, and the crimping lip is faced by a second tool also mounted on the end slide. When the finished shell is indexed into the lower back position of the machine, it is automatically released by the chuck jaws, after which the centering bar within the chuck moves automatically toward the left to push the shell out of the chuck and on the loading and unloading rest, as shown in Fig. 9.

Operations Performed on Six-spindle Automatics. — The six-spindle automatic shown in Fig. 11 is used for a series of cuts on the open or nose ends of shells. In the first working station, at the lower front of the machine, the shell is counterbored by a tool on the central slide, and rough-faced by a cutter on the swinging arm at the front of the machine, which is operated by a cam.

In the second working station, at the bottom of the machine, the shell is semi-finish counterbored by a tool on the central slide. In the third working station, at the lower

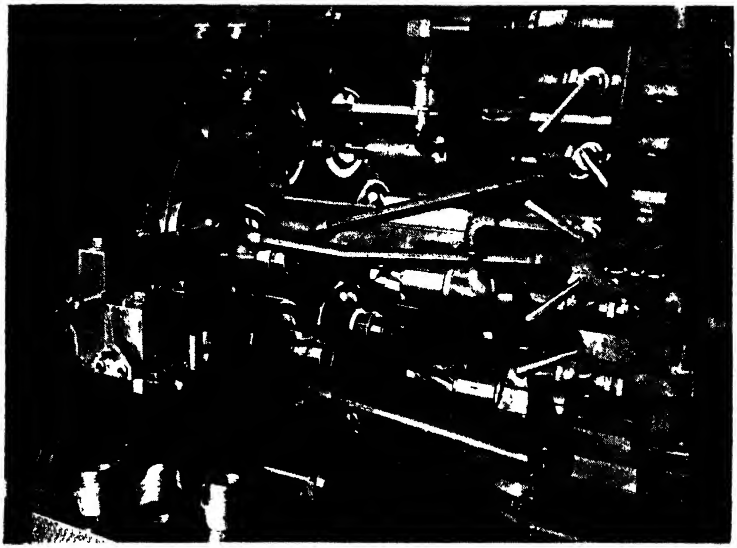

Fig. 13. Automatic Equipped for Producing Fuse Bodies from Cold-drawn Steel

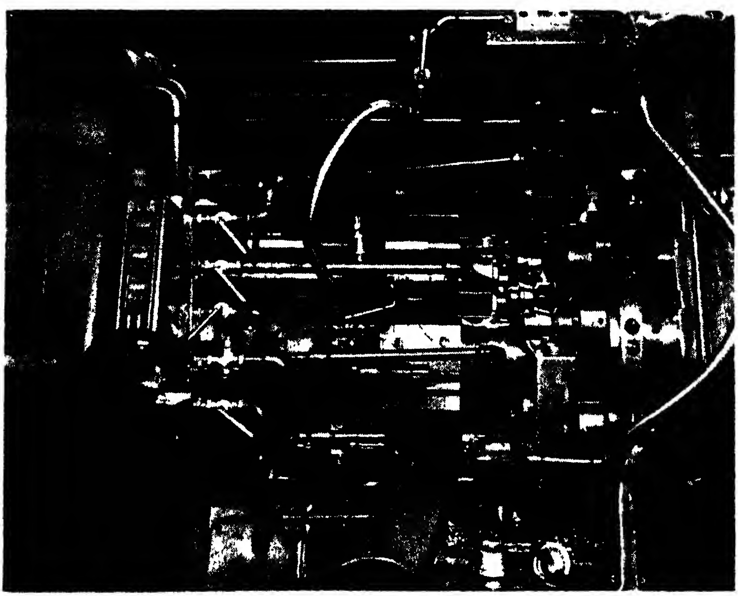

Fig. 14. Tooling on Rear Side of Automatic Shown in Fig. 13.

rear of the automatic, the shell is finish-counterbored by a tool on the central slide, and finish-faced by a cutter on a lower rear arm, which is also actuated by a cross-feed cam.

A tool on the central slide in the fourth working station is fed into the shell opening to a distance of approximately 1 1/2 inches, and then moved sidewise for cutting a recess to provide clearance for a tap used in the next station of the machine. The recessing tool also chamfers the outer end of the hole. Finally, in the top station of the automatic, the shell is threaded internally at the nose end by the use of a collapsible tap on the central tool-slide. The threads are 2 inches in outside diameter, and twelve per inch.

In Fig. 12 is shown a close-up view of a six-spindle automatic employed for producing the bolts used for fastening together the two halves of tractor differential casings. These bolts are 7/16 inch in diameter by 3 3/4 inches long, and are made from 0.45 to 0.50 per cent carbon-chromium steel. The production time is three minutes per bolt.

Machining a Fuse Body in 20 Seconds.— Fuse bodies of the type shown on the slides of the machine in Figs. 13 and 14 are produced at the rate of one piece every twenty seconds by the 2 5/8-inch automatic illustrated. The fuse bodies are produced from 2 7/16-inch cold-drawn free machining steel bars. In the first station of the machine, seen at the bottom in Fig. 14, the stock is fed forward to a stop which is first fed upward into line with the station by an angular slide, and then withdrawn to permit the application of a drill on the main slide. At the same time, a tool on the bottom rear slide rough-forms the external surfaces of the part.

The part is then indexed to the front bottom position, seen in Fig. 13, where a tool on the main slide drills to a larger diameter and roughs out the straight bottom of the hole. At the same time a tool on the front bottom slide semi-finish-forms the external surfaces. After the part has been indexed to the front middle position, a tool on the bottom slide finish-forms the external surfaces and partially cuts off the piece from the bar. At the same time.

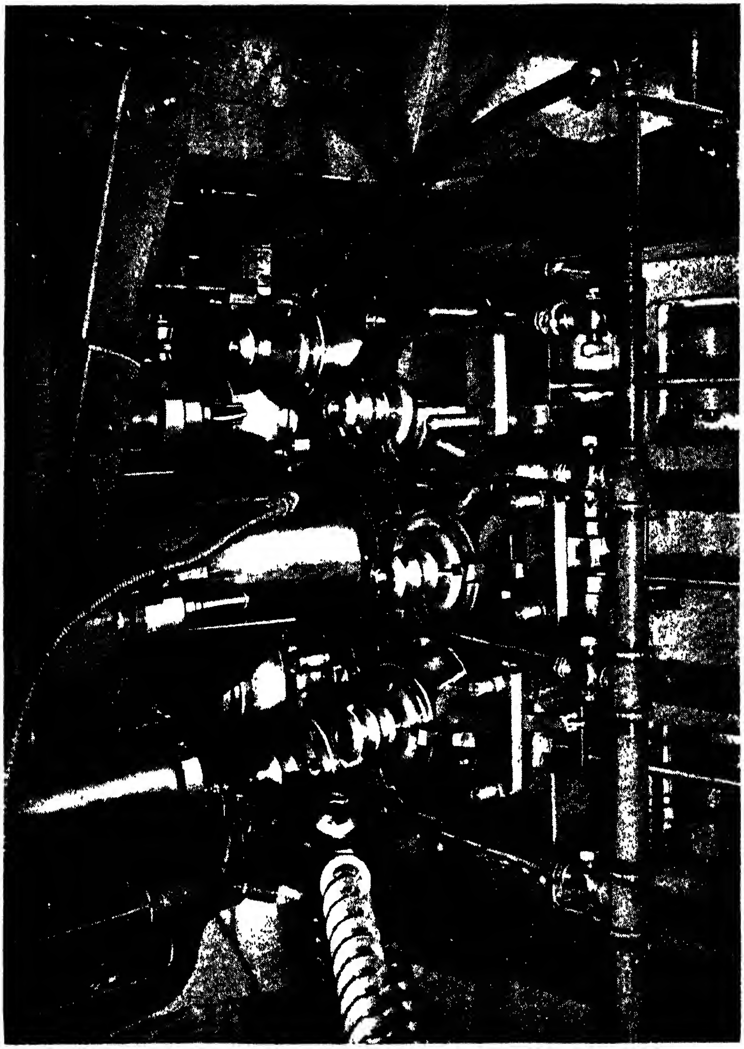

Fig. 15. Tooling Provided on an Eight-spindle Automatic which Produces Pinion Blanks

a tool on the main slide finish-reams the hole and faces the end.

In the front top position of the machine, a shaving cut is taken by a tool on the top slide to give a final finish to the external surfaces while a tap on the main tool-slide cuts the internal thread. Then in the rear top position, seen in Fig. 14, the external thread is cut by a die-head equipped with circular chasers, which is mounted on the main slide. At the same time, a tool on the rear top slide takes a second cutting-off cut. Finally, in the rear middle position, an arbor on the main slide advances and holds the piece, while a tool on the top slide completes the cutting-off operation. This piece has a maximum diameter when finished of approximately 2 3/8 inches, and is 2 3/16 inches long.

Machining Bevel Pinion Blanks on Eight-spindle Automatic.—In Fig. 15 is shown an eight-spindle automatic of 2 5/8 inches capacity engaged in producing bevel pinion blanks from bar stock at the rate of one every thirty-seven seconds. One of the features of this equipment is that, in addition to the more or less standard tools, there are two tools for burnishing a spherical surface on the back of the pinion blanks, as may be seen from the examples sliding down the chute at the front of the machine, and for burnishing a hole that extends through the blanks.

The tool that burnishes the spherical surface is mounted on the main slide in the top position, as illustrated, and consists of two cone-shaped rolls which are advanced against the end of the work under sufficient pressure to compress the metal on the pinion blank being formed. The two cone-shaped rolls are free to revolve with the work. The tool for burnishing the hole through the pinion may be seen on the main slide in the central front position.

In addition to the burnishing steps, each pinion blank is drilled three times, reamed, and chamfered by tools mounted in the various positions around the main slide, and is turned, faced, and cut off by tools on the front and rear cross-slides.

Automatic Machines which Turn Parts Held in Chucks

When individual castings or forgings must be machined in large quantities, a machine capable of performing all operations automatically is frequently employed. Such a machine may have a single chuck (or other work-holding fixture) and a tool-holding turret as well as tool slides which automatically bring the tools successively into the working position. This type of machine is similar to the turret lathe in its general appearance, but it performs the complete cycle of operations automatically.

Another type of automatic for parts which are held in chucks is vertical in design and has several work-holding chucks and tool-holding slides. When the machine is in operation, the chucks and work index periodically from one working position to the next; consequently, the tools at each position operate simultaneously and then withdraw so that every indexing movement brings a finished part to the first or loading position where it is replaced with a rough casting or forging. Examples of work on both the horizontal and vertical types of automatics just referred to will be found in this section.

Machining Pinion Blanks for Airplane Engines.—Fig. 1 shows an automatic equipped for machining the reduction pinion blanks of airplane engines. In a roughing operation performed on a similar machine, a series of turning and facing cuts is taken on one end and a 1/2-inch hole is drilled the full length of the part. The pinion forging is then transferred to the machine shown for taking rough and finish turning, facing, and boring cuts on the hub end, and also performing recessing and tapping. On the turret

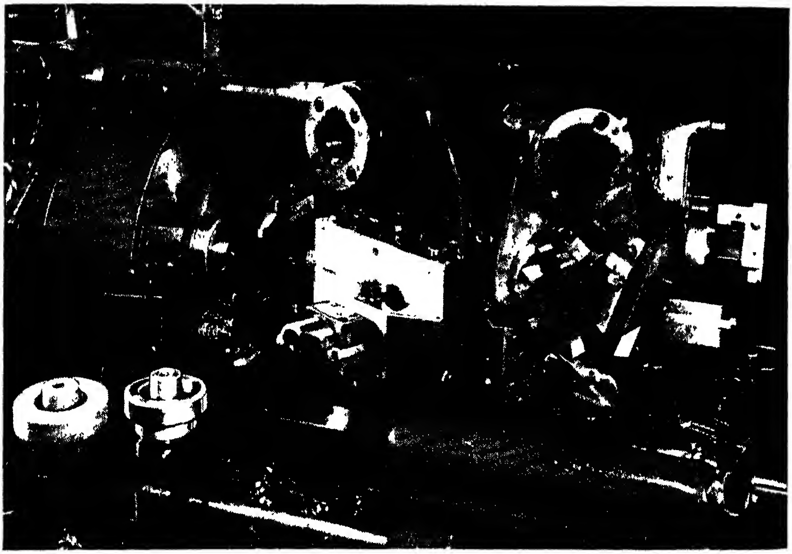

Fig. 1. Machining Reduction Pinion Blanks

Fig. 2. Machining Piston-pin Holes and Bosses

faces shown toward the front of the machine may be seen the tools employed for turning the gear blank diameter and machining the deep recess between the hub and the gear rim. At the end of this operation, the part is returned to the first automatic for finishing the other side.

Machining Pin Holes and Bosses of Pistons.—The automatic shown in Fig. 2 is for finishing the pin holes and bosses of pistons. Tools on the first face of the turret rough-bore both holes in line, the cutter-bar being moved upward after the front tool has entered the piston. This is accomplished by a roller at the top of the turret-slide engaging a slot in a cam-block mounted at the front end of the headstock. Tools on the second face of the turret chamfer the outer end of both holes, these cuts also being taken by the tool-slide being pulled upward through the engagement of a roller with a second cam slot on the headstock, positioned at an angle of 12 degrees for obtaining the desired angle of chamfer.

The inside faces of the piston bosses are next faced by tools on the third side of the turret, which are fed crosswise by a block on the cross-slide pressing against the tool-slide on the turret. The piston-pin holes are then semi-finish bored by tools on the fourth turret face, which are moved upward in the same manner as the rough-boring tools, after which recesses are cut in the piston-pin holes by tools on the fifth turret face. These tools are operated horizontally by the cross-slide in the same manner as the facing tools on the third turret face. This one machine turns out pistons as rapidly as three previous machines.

Applications of Two-spindle Type of Automatic Chucking and Turning Machine.—The two-spindle type of automatic chucking and turning machine enables either two identical operations to be performed simultaneously, or two different operations to be performed at one time if the diameters and lengths of the principal cuts are approximately the same in both operations. In the latter case, a piece of work can be completely machined within one cycle of the turret, usually by turning the piece end for end for

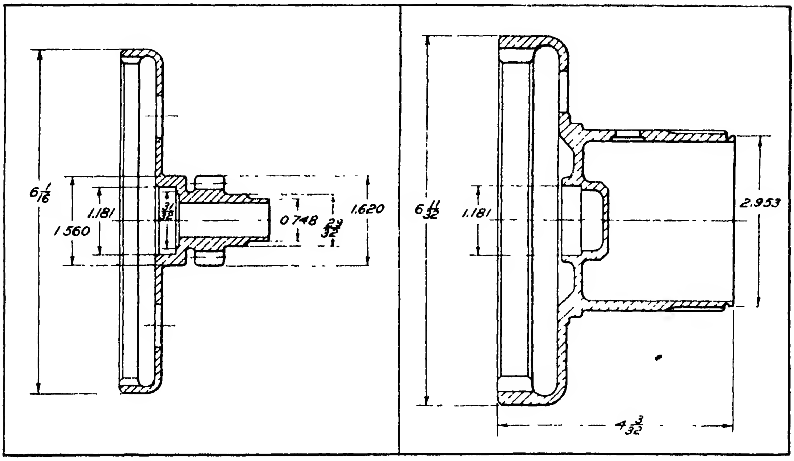

Fig. 3. (Left) Cross-section of Gear for Aircraft Controllable-pitch Propellers. Fig. 4. (Right) Cross-section of Another Gear Used in Aircraft Controllable-pitch Propeller Assemblies

the second chucking. The machining of two pieces at the same time is made possible by two sets of tools on each turret face. A cross-slide unit operates in conjunction with the turret-slide, thereby providing for the taking of rough- and finish-facing cuts. Slide tools can also be mounted on the turret for taking facing, recessing, or similar cuts that require sidewise movement of the tools after they have been advanced into the work.

The gears shown in Figs. 3 and 4 are machined from steel forgings in four chuckings. The first two operations are performed simultaneously, and consist in rough-machining the forged blanks. Then, following heat-treatment, the two finishing operations are also performed on the two parts simultaneously.

Referring to Fig. 3, for the first chucking, the large open end of the piece is turned toward the spindle (see rear spindle, Fig. 5). It is gripped on the outside diameter by a three-jaw chuck. The operations on the projecting end of the gear are: (1) Spot-drill hole; (2) drill hole half way; rough-turn 29/32-inch diameter; rough-face shoulder; (3) rough-turn outside diameter to the jaws; rough-

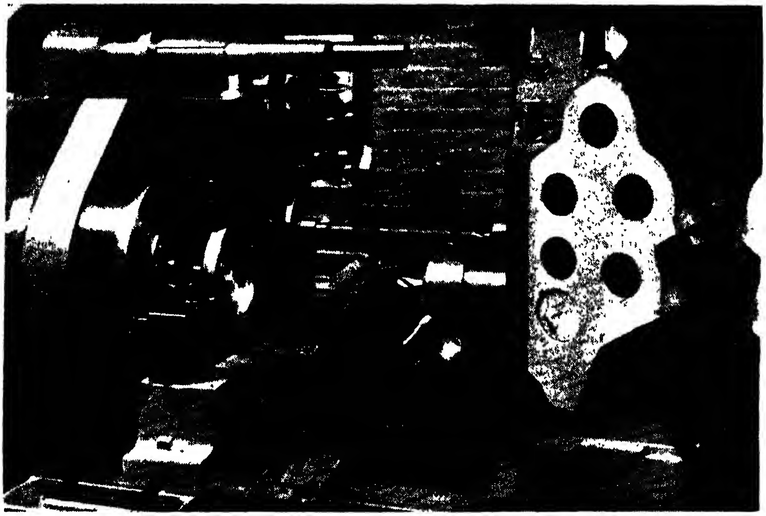

Fig. 5. Machining the Gear Shown in Fig. 3 on a Two-spindle Automatic Chucking Machine

Fig. 6. Machining the Gear Illustrated in Fig. 4 on a Two-spindle Automatic Chucking Machine

turn outside diameter of small gear; rough-face end of hub; (4) rough-face back side of small gear with slide tool; (5) semi-finish turn outside of small gear; (6) finish-turn outside of small gear to 1.620 inches.

Now the small end of the gear is turned toward the spindle. (See front spindle, Fig. 5). The gear is gripped on that part of the large outside diameter that was machined in the previous operation. The machining operations then follow: (1) Spot-drill hole; (2) drill hole through; (3) rough-turn outside diameter to jaws; rough-bore inside of large gear diameter; machine 1.181-inch diameter counterbore; (4) rough-face web and form gear cutter clearance "groove" with single-point tool held in slide; face end at rim; (5) semi-finish bore inside of large gear diameter; (6) finish-bore inside of large gear diameter.

The parts, now being rough-machined all over, are heat-treated to 310 Brinell, and are then ready for the semi-finishing and finishing operations. In the first chucking, the large end of the gear is held toward the spindle, the gear being gripped on the outside by three jaws. The machining operations are as follows: (1) Semi-finish turn the outside of the small gear; semi-finish turn the 1.560-inch diameter; machine groove for gear-cutter clearance; finish-turn 29/32- and 0.748-inch diameters; (2) semi-finish face back of gear with slide tool; face outside rim; (3) take finish cuts on the same surfaces as in (1) except the groove; (4) finish-face back of gear with slide tool; form radius at large diameter of piece; face rim; finish groove; (5) break corners where necessary; turn gear diameter to size; (6) turn 1.560-inch diameter hub to size. Allow from 0.005 to 0.008 inch for grinding where required.

For the final operation, the small gear end is turned toward the spindle, the gear being gripped, as before, by three chuck jaws. The machining operations are: (1) Semi-finish bore the large gear diameter; semi-finish 0.181-inch counterbore and 31/32-inch counterbore; (2) semi-finish face web with slide tool; (3) finish-bore inside of large gear diameter; bore hole; (4) finish-face web; finish-face rim with slide tool; (5) ream hole; chamfer corners;

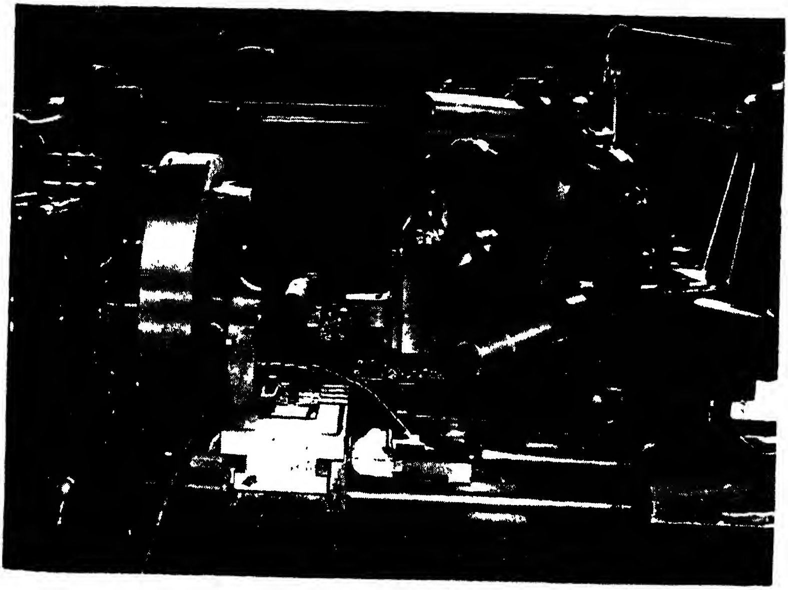

Fig. 7. Roughing a Steel Crankcase for Airplane Engine

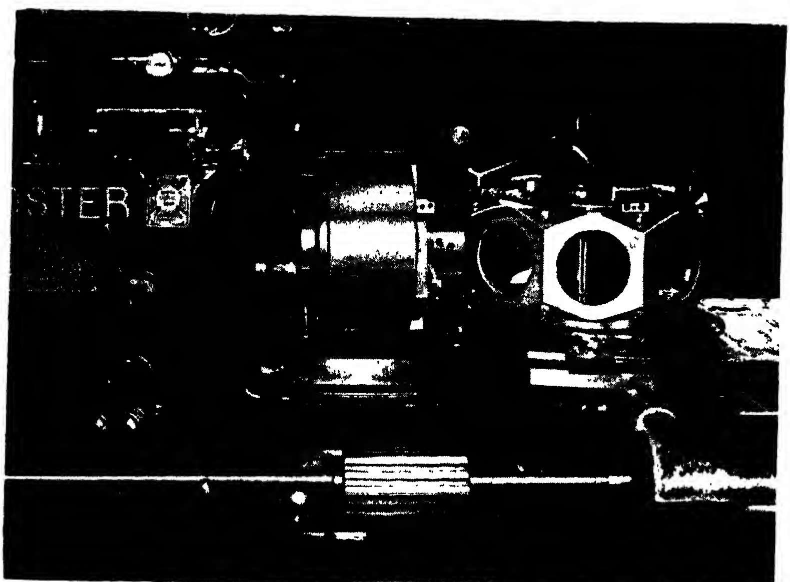

Fig. 8. Boring and Facing Pads on Assembled Crankcase

(6) finish counterbore. Allow from 0.005 to 0.007 inch for grinding where required. This completes the operations on the automatic chucking and turning machine on the piece shown in Fig. 3.

The machining time for the first and second chuckings, simultaneously performed, is 18.5 minutes, and the floor-to-floor time 19.5 minutes. The production per machine, allowing for idle machine time, is conservatively estimated at two and one-half gear blanks completely roughed per hour. The machining time for the third and fourth chuckings, simultaneously performed, is 46.61 minutes, and the floor-to-floor time 47.5 minutes. The production per hour per machine, making ample allowance for idle time, is one gear blank, completely finished. One operator can readily handle three machines on this class of work.

For machining the part shown in Fig. 4 the procedure is approximately the same. The two work positions are shown in Fig. 6. The total machining time for the first two operations, simultaneously performed, is 26.22 minutes, and the floor-to-floor time 27.0 minutes. With due allowance for idle machine time, two gear blanks are completely roughed per hour. The third and fourth operations, simultaneously performed, require 48 minutes, the floor-to-floor time being 50 minutes. Allowing for idle machine time, one complete gear is finished per hour.

Machining Airplane Engine Crankcases.—Fig. 7 shows an automatic arranged for machining airplane engine steel crankcase halves from the rough forgings to parts completely finished, except for drilling and grinding operations. These forgings are of a chromium-nickel-molybdenum steel and weigh 164 pounds in the rough. Their weight is only 45 pounds when machined. The forgings have a hardness of between 241 and 285 Brinell.

The first operation on the inside of the crankcase half is performed in the machine shown in Fig. 7 after the closed side has been faced and the legs turned externally, also in an automatic. In the operation illustrated, roughing and semi-finishing cuts are taken on all the inner surfaces. In the taking of wide facing cuts, tools on the turret are fed

across the work by a plunger on the rear cross-slide. Chips are cut as heavy as 1 1 8 inches wide by 0.015 inch thick.

After the crankcase halves have been completely turned and faced, they are drilled on another type of machine to enable the two halves to be assembled; then they are returned to the machine illustrated in Fig. 8 for rough- and finish-boring each cylinder bore, chamfering these bores, and facing the surrounding pads. The pad facing cuts are taken by a tool on a slide that is mounted on the chuck and is fed radially after the boring tools have reached the end of their movement. Dimensions of surfaces are held generally to tolerances of plus or minus 0.003 inch, while the hub bore diameter must be maintained within plus or minus 0.001 inch. These machines are equipped with hydraulically operated turrets and air-operated chucks.

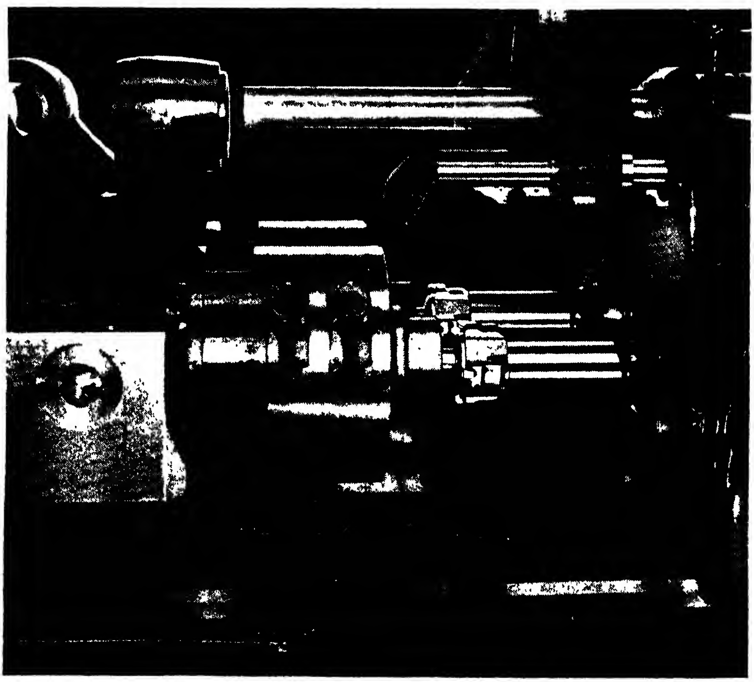

Fig. 9. Rough-boring Cylinder Barrels on an Automatic in which the Forgings are Held Stationary on the Turret while the Tools Revolve

An Automatic which Holds Work on the Turret. — An automatic is shown in Fig. 9 for rough-boring cylinder barrels. This machine differs radically from the conventional design of such machines in that the work-pieces are mounted on the turret and held stationary during the operation while cuts are taken by revolving boring-heads driven from the machine headstock. The four-sided turret of this machine is equipped with two chucks on two sides so that cylinder barrels can be loaded on one side while the cylinder barrels supported on the opposite side are being bored. Chucks could, of course, be furnished on all four sides of the turret if desired. The chuck jaws are tightened and loosened by the application of a crank-handle. The rough 5 5/16-inch holes in the cylinder barrels are bored in this operation to a diameter of 5.475 inches, within plus or minus 0.005 inch, the barrels being 9 1/2 inches long. Accuracy is insured by two guide bars on the headstock that enter bushings provided at the top of the turret as the latter advances to feed the cylinder barrels past the cutters. There is also a long pilot-bar projecting forward from each chuck that enters a bushing in the headstock. Four cutters are provided on each tool-head.

Machining Shells on Vertical Type of Automatic.—Some machining operations on the nose ends of 81-millimeter M56 shells are illustrated in Fig. 10. These shells are produced from seamless steel tubing. Two automatics are used. A six-station machine is equipped for finishing the "nose" end of the shells, and an eight-station machine is used for machining the "tail" ends. This particular make of automatic is commonly designated by the trade name "Mult-Au-Matic." A close-up view of the tooling on the six-spindle Mult-Au-Matic is illustrated in Fig. 10. No cuts are taken on the shells in the first or loading station, this being the customary practice. In the second station, the rounded nose of the shell and the bourrelet are rough-turned. In the third station, the bourrelet and a diameter in back of the bourrelet are finish-turned, and the shell is rough-bored at the nose end. In the fourth station, the nose end is rough- and finish-faced, and chamfered.

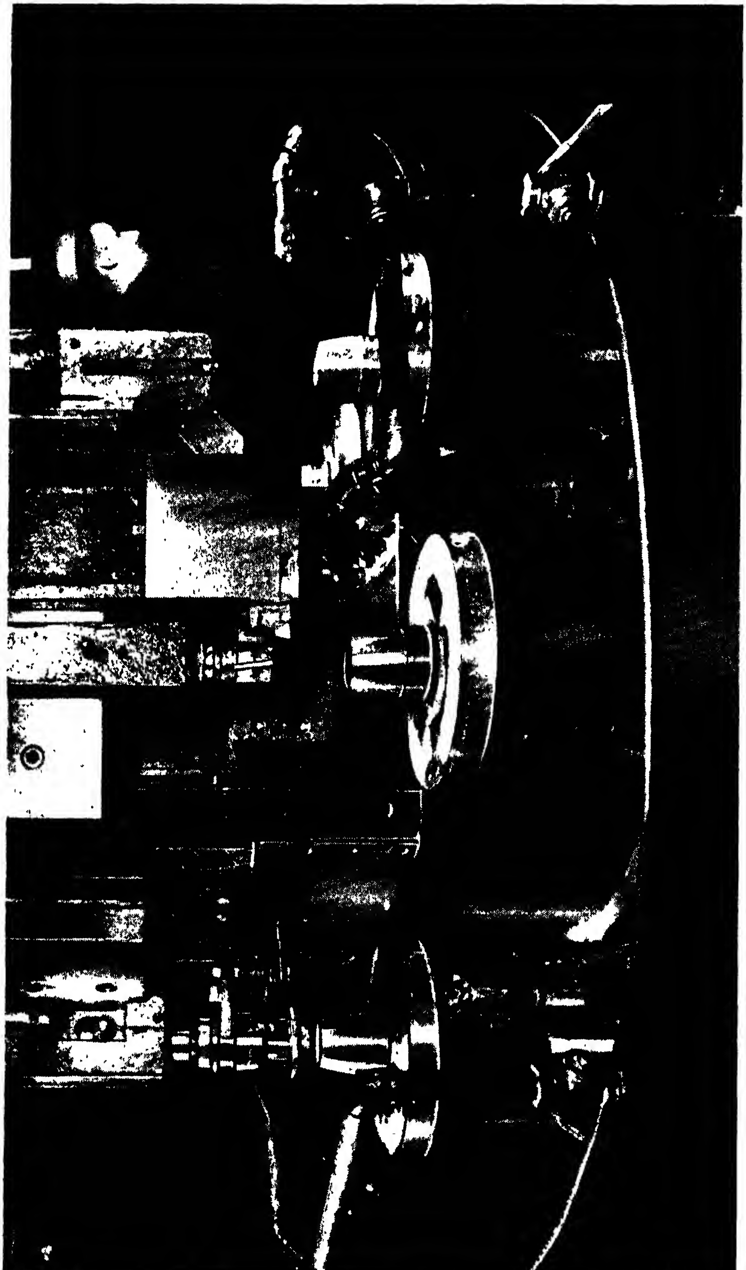

Fig. 10. Tooling Equipment Provided on Mult-Au-Matic for Machining Nose End of Shells Produced from Seamless-steel Tubing

The contour of the nose is finish-turned in the fifth station, and the bored hole in the nose end is reamed to the minor diameter of the threads to be tapped in the sixth station. This tapping operation is performed with a collapsible tap. The fourth, fifth, and sixth stations of the nose finishing are seen in Fig. 10.

When the shells are indexed to the second station of the eight-spindle machine, a cartridge container hole is drilled in the tail end, the bourrelet on that end is rough-turned, and a recess is cut in the shell contour to provide a starting point for a turning tool employed in a following station of the machine. In the third station, a hole is drilled for a 1/8-inch pipe plug. The sharply tapered surface on the tail end is rough-turned in the fourth station.

In the fifth station, the bourrelet on the tail end is semi-finish-turned and, at the same time, the cartridge container hole is step-counterbored. In the sixth station, the bourrelet is finish-turned, and the cartridge container hole is reamed to two diameters by employing a step type reamer. In the seventh station, the end of the shell is rough- and finish-faced, the cartridge container hole chamfered, and four grooves are machined in the bourrelet by a form cutter. Finally, in the eighth station, the contour of the tail end is finish-turned, and the outside corner of the tail chamfered.

Machining Airplane Engine Cylinder Heads. — A six-station Mult-Au-Matic tooled up for machining the combustion chamber in cylinder heads is illustrated in Fig. 11. The first station of the machine is used for loading only. In the second station, tools are fed straight down for rough-boring the thread band and shrink band, and "spotting" the dome. At the same time, a side tool rough-turns the flange.

In the third station, the dome is rough-turned to the required contour by the use of a tool which is swiveled to the proper radius after it has been fed into the cylinder head. The swiveling action is obtained through the sidewise movement of a cross-slide on the tool-head. This station is seen in the center of the illustration. In the next station, which

is seen at the left, sets of tools are applied on both sides of the work for rough- and finish-facing two steps on the flange. On one side, the tools cut from the outside of the flange toward the center of the work, and on the other side, from the inside of the flange toward the outer edge. The sidewise movements commence after the tools have been fed down.

The fifth station of the machine is tooled up for finish-turning the dome by means of tools similar to those used in the third station. Finally, in the sixth station, a large reamer finishes the thread and shrink bands and cuts a bevel clearance for the piston. At the same time, a side

Fig. 11. Machining Dome, Thread and Shrink Bands, and Flange of Cylinder Heads

tool finish-turns the periphery of the flange, and another side tool rounds the outer flange corner.

Machining Automobile Engine Flywheels.—In one of the large automobile plants, a battery of eight Mult-Au-Matics rough- and finish-machines the flywheels. All turning, facing, and boring cuts are taken on both sides of the flywheels in two operations. The machines are arranged in two rows of four each with a chip conveyor between them. Those on one side of the conveyor machine the clutch side of the flywheels in the first operation, and those on the opposite side finish the motor side of the flywheels in the second operation. The flywheels are high-grade iron castings.

The rough flywheel castings are brought to the battery of machines on an overhead conveyor and are passed from the first- to the second-operation machines on roller type gravity conveyors. From the second operation, the flywheels are again loaded on the overhead conveyor to be transferred to other machines in the department.

The tooling for the first operation, and at the various working stations, is shown diagrammatically in Fig. 12. In the loading station there is a hydraulic locating device which holds the work central in the chuck until the jaws grip it securely around the periphery. A dial indicator on the locator housing shows the pressure applied by the locating plunger. The chucks are of three-jaw design. The work-table indexes from right to left around the machine column, carrying the flywheel successively to the five working stations and back to the loading station.

In the second station, tools on a plain vertical head move downward at a feed of 7/16 inch per work revolution to cut groove *E* (see loading station diagram) and a second groove to start the machining of surface *B* at its maximum diameter, and to chamfer corner *D*.

In the third station, tools on a plain vertical head move downward for rough-turning periphery *C* and cutting another groove in surface *B*, the feed in this case being 17/32 inch per revolution. In the fourth station, Fig. 13, tools on a plain compound head are fed horizontally after having been moved downward to the required depth, for

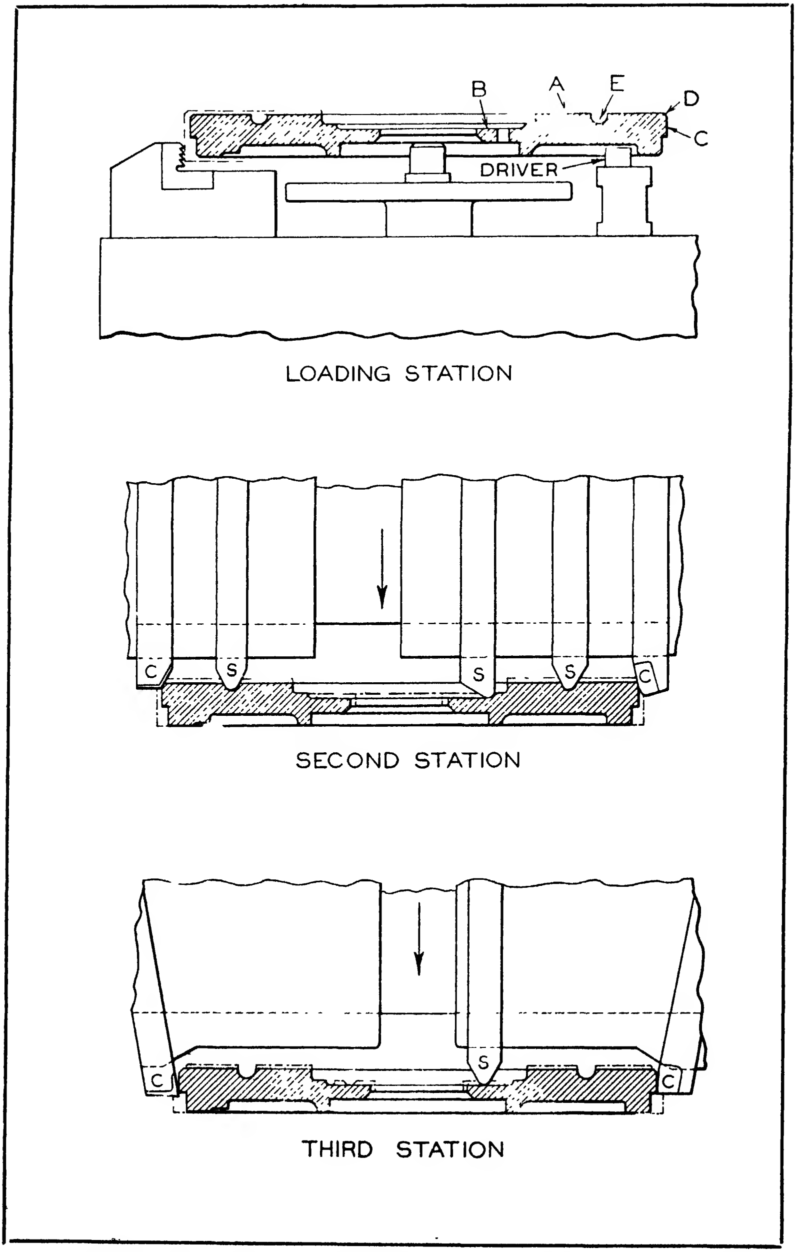

Fig. 12. Tools for First Series of Operations on Flywheels

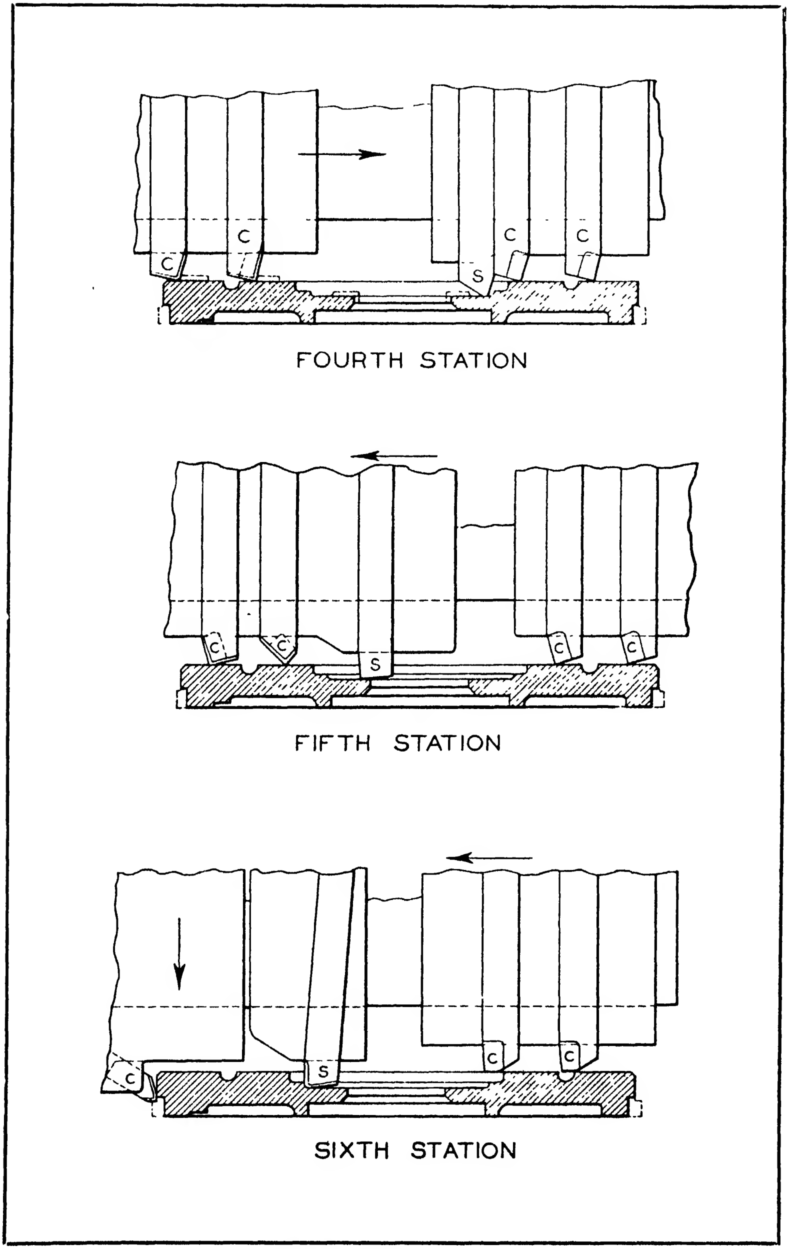

Fig. 13. Tools for First Series of Operations on Flywheels

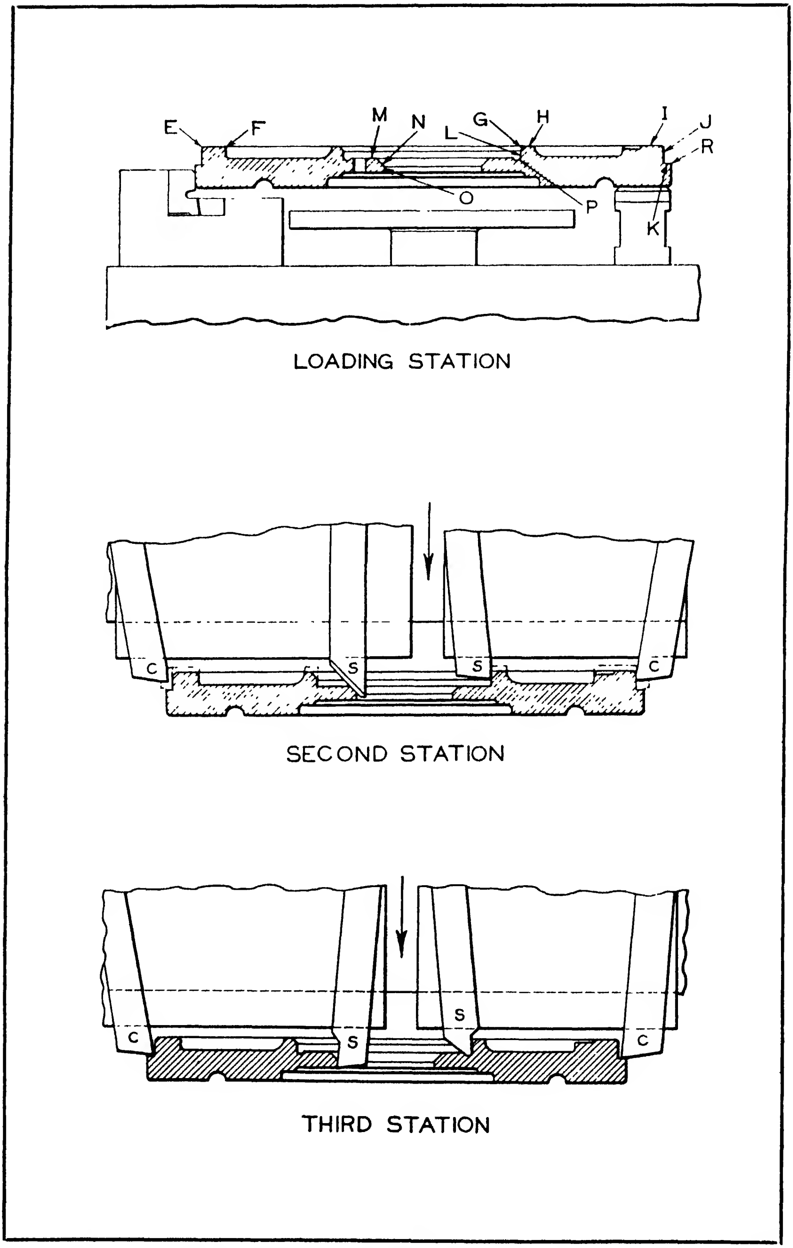

Fig. 14. Tools for Second Series of Operations on Flywheels

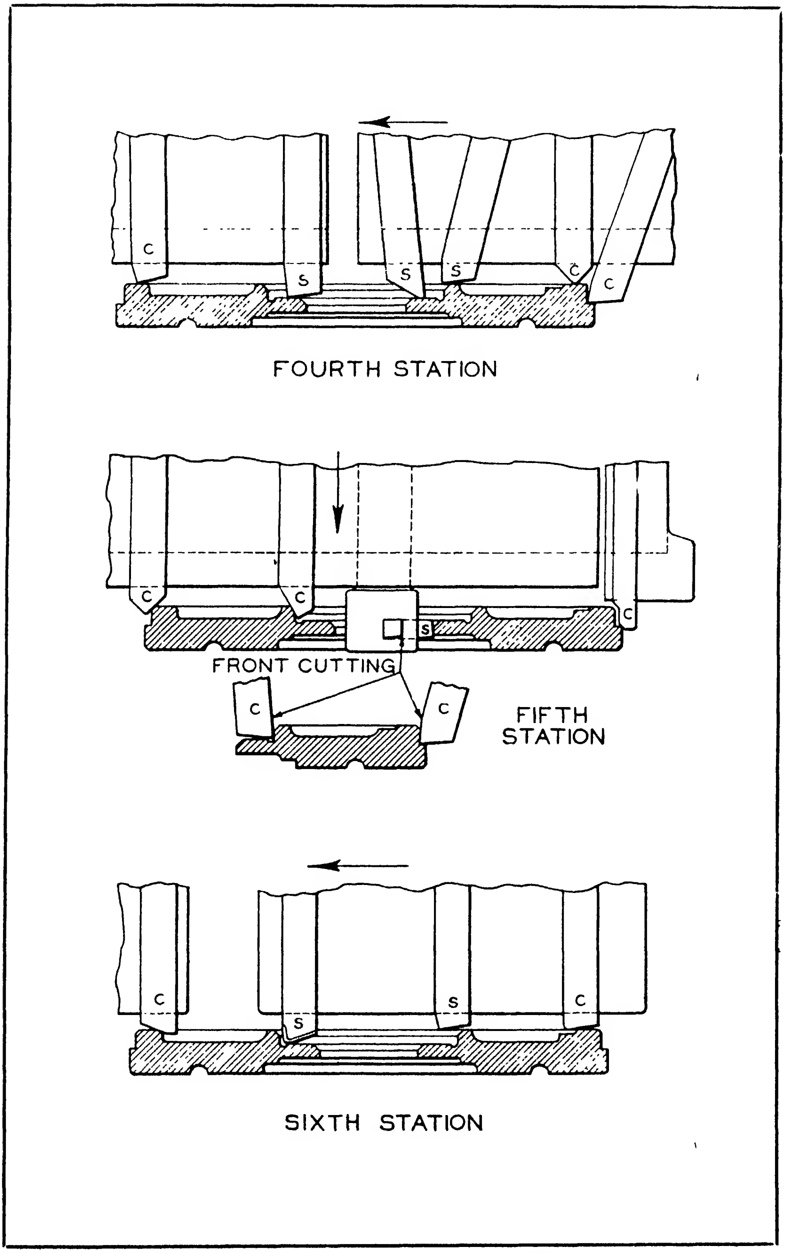

Fig. 15. Tools for Second Series of Operations on Flywheels

rough-facing approximately one-half the width of surfaces *A* (Fig. 12) and *B*, the feed being 9/16 inch per work revolution.

The fifth station is provided with a second plain compound head which moves tools horizontally in the opposite direction to the tool movement in the fourth station, for rough-facing the remainder of surfaces *A* and *B*. The feed in this case is 5/8 inch per work revolution.

Finally, in the sixth station, tools on a plain compound head equipped with an auxiliary turning tool are fed downward for finish-turning rim *C* and sidewise for finish-facing surfaces *A* and *B*. The turning tool is fed downward at the rate of 3/4 inch per work revolution, while the facing tools are fed horizontally at approximately 2 inches per work revolution.

When the flywheel again reaches the loading station, an elevating mechanism lifts it clear of the chuck jaws, so that the machine operator can slide the casting to the roller gravity conveyor without actually lifting it. All the tool-heads of the machine are accurately guided in relation to the flywheels by bushings on the tool-heads sliding over vertical posts provided on the indexing table of the machine.

Figs. 14 and 15 show diagrams of the tooling employed in the second operation, which is performed on the motor side of the flywheels.

Referring to the reference letters in Fig. 14 and on the diagram for the loading station, it will be seen that in the second station, tools on a plain vertical head are fed downward for rough-boring shoulder *L*, chamfering corner *N*, and rough-turning part of surface *J*. This tool-head is fed downward at the rate of 3/8 inch per work revolution.

In the third station, the tools on a plain vertical head are fed downward at the rate of 13/32 inch per work revolution for rough-turning the remainder of surface *J*, rough-boring hole *O*, finish-boring shoulder *L*, and turning recess *P*.

The fourth station of the machine (Fig. 15) is equipped with a plain compound head which is fed horizontally at the rate of 9/16 inch per work revolution for rough-facing

surfaces *H*, *I*, *K*, and *M*. The fifth station is equipped with a plain vertical head that is fed downward at the rate of 9/16 inch per work revolution for finish-turning surface *J*, finish-boring hole *O* and shoulder *L*, and chamfering corners *E*, *G*, and *R*. Finally, in the sixth station, there is a plain compound head that is fed horizontally at the rate of 31/32 inch per work revolution for finish-facing surfaces *H*, *I*, and *M*, and for chamfering corner *F*.

Proper setting of all tools is insured by gages permanently mounted on the machines. These gages are attached to swinging holders that are fastened to the tool-heads. By swinging these holders downward and applying feeler gages between the gage-blocks and the tools, the settings of the tools can be readily ascertained and adjustments made.

All of the chips and coolant coming from the machines drain down troughs to a central trough and chip conveyor which lead to a coolant pit in the floor. The coolant flows into the pit, and the chips are carried there by a link chain conveyor. The chips are transferred from the coolant pit by a vertical bucket conveyor to an overhead hopper, from which they can be discharged on trucks. The coolant is filtered and recirculated to the machines. This arrangement has greatly facilitated the disposal of the chips and the reclaiming of the coolant.

Application of Eight-spindle Vertical Machine to Shells.—Three-inch and 75-millimeter shells are machined on an eight-station Mult-Au-Matic after the finish-turning operation. Two of the stations at the front of this machine are used for loading, each shell being passed twice around the machine, first with the nose up, and then with the base end up. The machine indexes through two stations at a time. Special devices facilitate loading of the shells in the chucks.

A close-up view of the first and second working stations on this machine is shown in Fig. 16. In the first, at the right, the mouth of the shell is rough-bored and a short turning cut is taken. In the second station, the center lug extending from the base end of the shell is cut off by one

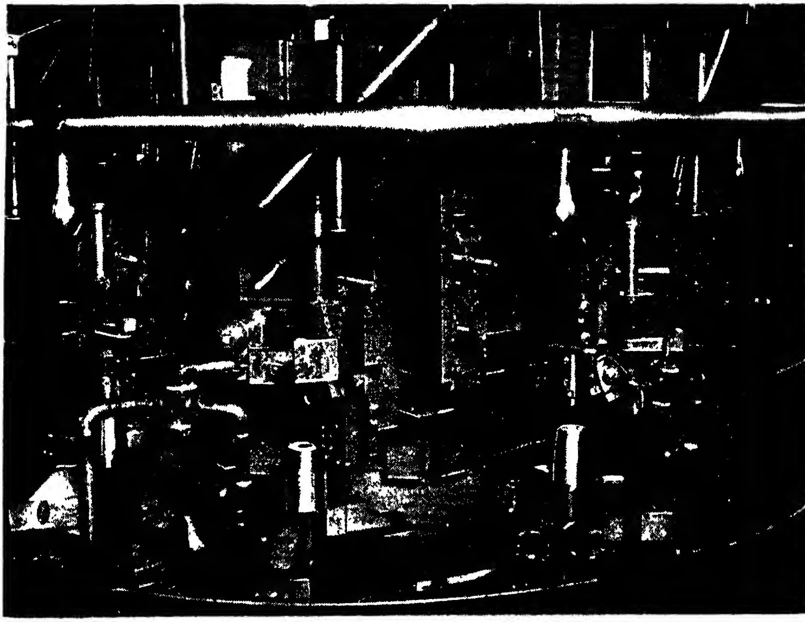

Fig. 16. Two Operations in a Series on Artillery Shells

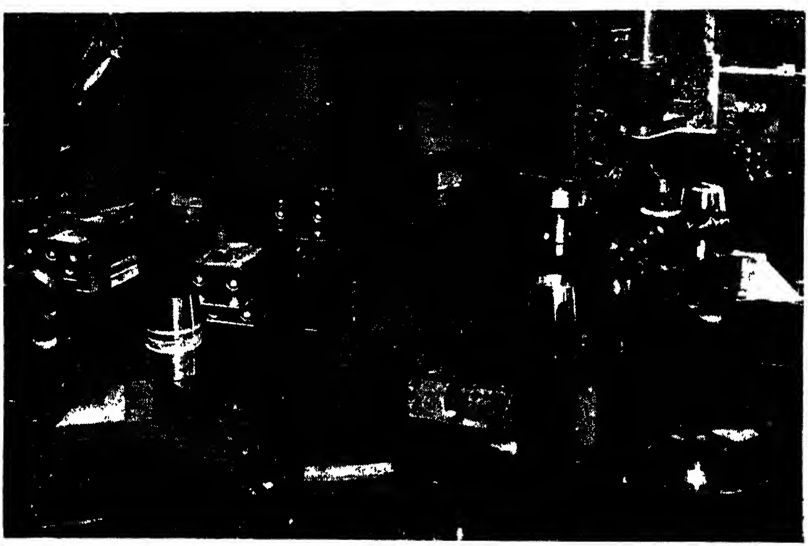

Fig. 17. Third and Fourth Operations on Shells

tool, and at the same time, a second tool rough-faces the entire width of the base.

In the third working station, which is seen at the right in Fig. 17, the mouth end is finish-bored and an internal recess is cut by a second tool on the same spindle, which is fed radially after the boring tool has reached the bottom of its cut. The nose of the shell is also finish-faced in this station by a third tool on a block mounted at an angle on the lower end of the tool-head.

In the fourth working station, which is seen at the left foreground, the band seat is turned on the outside of the shell by a form cutter, which simultaneously produces a series of grooves about 1 16 inch deep. This cutter is fed sidewise into the work after the tool-head has first been

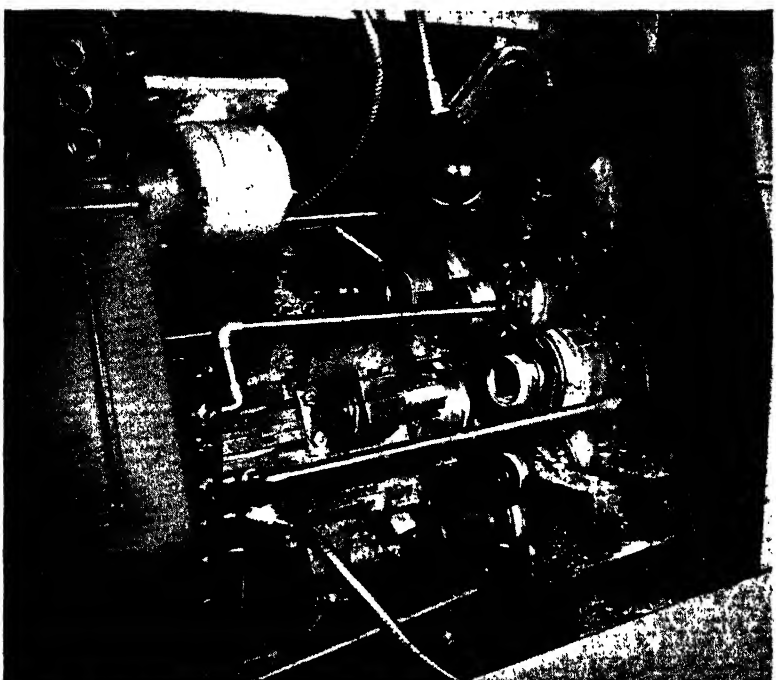

Fig. 18. Eight-spindle Automatic Set up for Roughing Pistons in Two Passes Through the Machine which is Double-indexed

lowered to the proper height. In the fifth working station a collapsible tap is employed to cut a 2-inch American screw thread, twelve per inch, in the shell nose. The sixth working station is used for finish-facing the shell base and for turning off the feather edge. Each working station of the machine is equipped with gages to insure correct setting of the tools. The boring tools, however, are set radially by means of hand gages.

Machining Pistons on Eight-spindle Machine of Horizontal Design.—Eight-spindle chucking automatics employed for roughing and finishing cast-iron pistons are shown in Figs. 18 and 19. In the roughing operation, the pistons are passed twice through the machine, the automatic being double-indexed for this purpose. For the first pass around

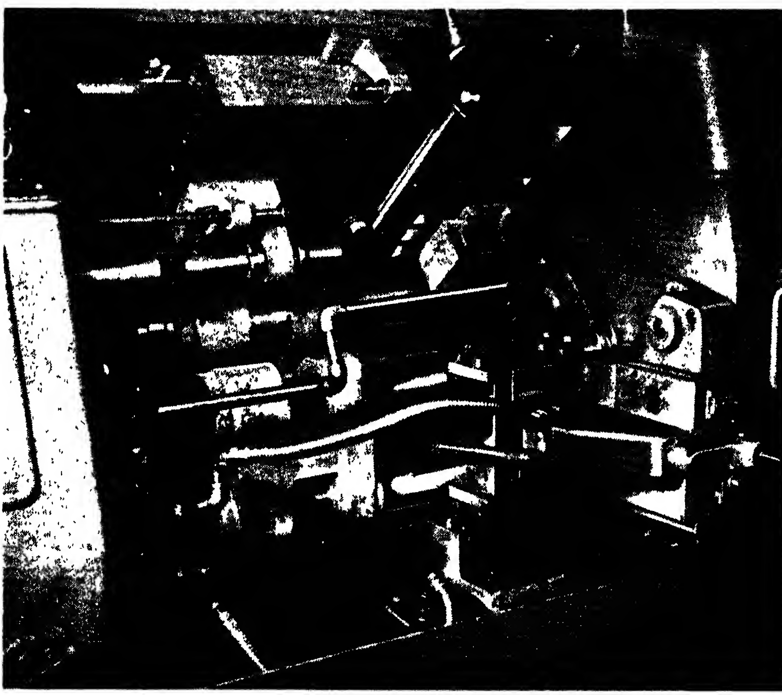

Fig. 19. Automatic Employed for Finish-turning, Finish-facing and Cutting the Ring Grooves on the Pistons

the machine, the piston is mounted on a pin chuck, with the closed end extending toward the central tool-slide; and for the second pass, it is held in a collet chuck from the rough-turned closed end, with the skirt extending toward the central tool-slide.

In the first pass around the machine, the piston is rough-turned for one-half its length, starting from the closed end, by tools on the central slide in the lower front position of the machine; faced to length on both ends by tools on the lower rear slide, as seen in Fig. 18; and finished to length by tools on the upper rear slide. A center hole is also drilled in the closed end during the finish-facing by a drill mounted on the central slide.

In the second pass of the pistons through this roughing automatic, the remaining length is turned in the bottom position of the spindle-carrier; the open end is bored in the rear middle position of the machine; and the open end is reamed in the upper front position of the machine, all tools being mounted on the central slide. Tungsten-carbide tools and soluble oil are used in the roughing operation, and production is maintained at an average rate of 150 pistons an hour per machine.

The automatic employed for finishing the pistons is also arranged for double indexing; but in this case, the pistons pass around the machine only once, two sets of tools being provided, so that two pistons are finished with each indexing. The pistons are located on plug adapters in the reamed open end, and the outer closed ends are supported by spring-loaded air-operated live tailstock centers on an indexing carrier substituted for the conventional central tool-slide. This machine indexes over the top rather than around the bottom, as in the case of the roughing machine.

In the first two stations at the top of the machine, the pistons are finish-turned the full length by tools mounted on side slides at the front and rear of the machine. Then, in the two rear central positions, seen in Fig. 19, tools on a side slide are applied for finish-facing the pistons to length and cutting three ring grooves. Pistons in the bottom positions of the machine are finish-grooved by side-

heads at the front and back. Mineral seal oil is used in this operation as a lubricant, with the result that the grooving tools last for an entire day, whereas they had to be changed every two hours when other coolant was used. All tools in the finishing operation are also tungsten-carbide tipped.

Machining Cylinder Heads of Tank Engines.—An automatic used for machining the cylinder heads of Army tank engines is shown in Fig. 20. The work is held by means of a three-jaw air-operated chuck. Tools on the first face of the turret rough-bore the thread and shrink fits, and rough-turn the outside diameter at one end. A tool on the second turret face then rough-machines the spherical inside of the combustion chamber. During this cut, the tool is fed through the required arc by an arm at the back of

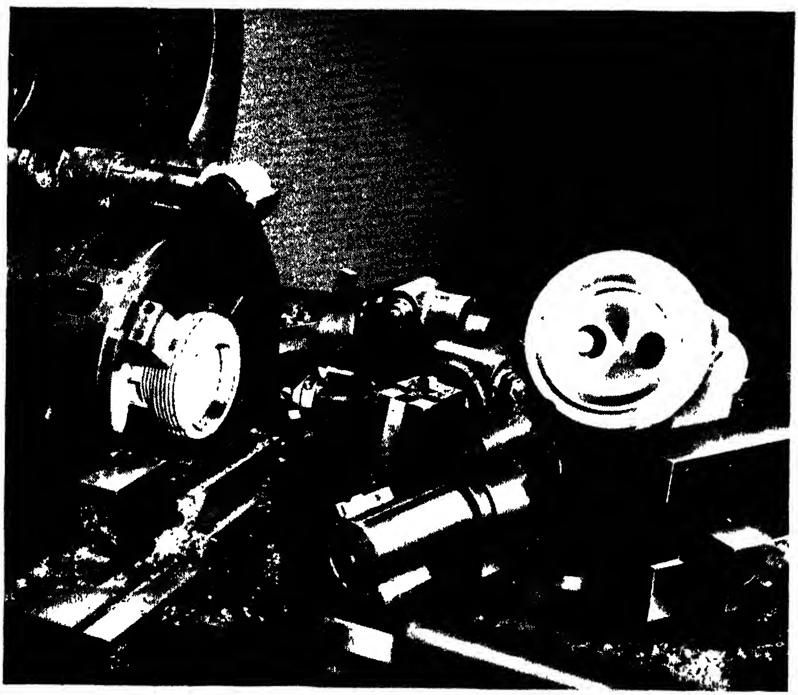

Fig. 20. Automatic Used for Machining the Combustion Chamber and Other Surfaces on Cylinder-head Castings

the cross-slide which advances against a plunger on the head carrying the spherical surface turning tool. Steady support is afforded to this tool by the engagement of a pilot block at the bottom of the turret face with ways in the center of the carriage. While this spherical turning cut is in progress, the end of the cylinder head is rough-faced by a tool at the back of the cross-slide. The combustion chamber is finished by a tool on the third turret face, which is operated in a similar manner to the one on the second face. Then tools on the fourth turret face turn a pilot surface and also finish-face the end of the cylinder head. Finally, tools on the fifth turret face finish-bore the thread and shrink diameters and finish-turn the flange.

Turning, Boring and Facing Brake-drums. — Brake-drums, of nickel-alloy iron, 19 inches in diameter by 6 1/4 inches wide, are completely machined in one operation on the automatic illustrated in Fig. 21. The drums are securely held in the jaws of an air-operated chuck, which grips the drum periphery. The operation consists of finishing the large bore to 17 1/4 inches diameter, within plus or minus 0.005 inch, for a length of 5 11/16 inches; boring a hole in the hub end to a diameter of 8.000 to 8.004 inches; facing both sides of the wall on the hub end; facing the open end; and turning the periphery of the drum for a width of 2 1/2 inches.

Three tools on the first turret face rough-machine the large bore, a fourth tool rough-bores the hole in the hub end, a fifth tool turns the outside diameter of the drum, and a sixth tool cuts a 1/4-inch by 45-degree bevel at the outer end of the large bore. The tools mounted on this turret face are seen at the right in the illustration.

Two tools attached to a slide mounted on the second face of the turret, face both sides of the wall on the hub end of the drum. In addition, one of these tools forms the beveled fillet at the inner end of the large bore. These cuts are accomplished by a bar on the rear cross-slide pushing the turret-slide sidewise after the tools have been fed into line with the surfaces to be machined, and thus causing the tools to feed across those surfaces. Upon the completion

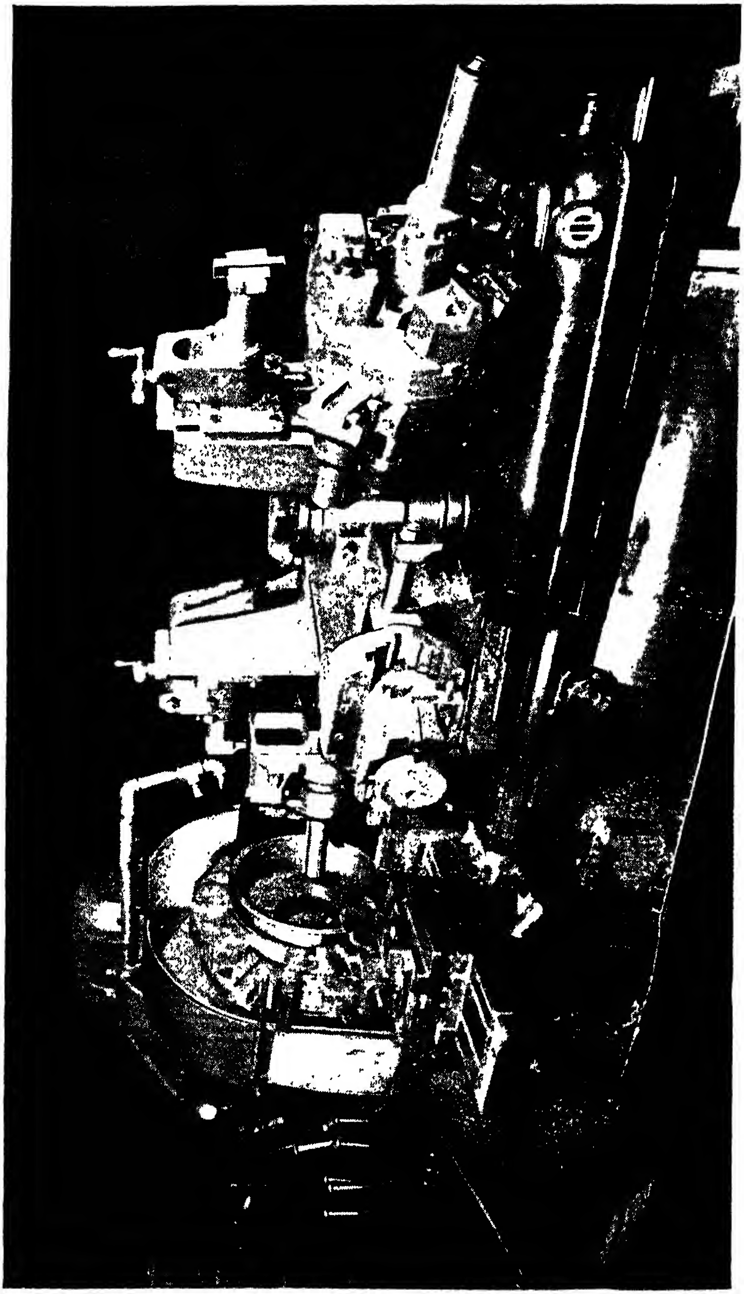

Fig. 21. Automatic Tooled up for the Complete Machining of Large Brake-drums

of the cuts, the tool-slide returns to its central position on the turret face, permitting the tools to be withdrawn. The cutters face to a diameter of about 13 inches. While the facing cuts on the hub end are in progress, a third tool on the rear cross-slide rough-faces the flange on the open end of the brake-drum.

Tools on the third turret face finish-bore the braking surface and the hole in the hub end, and finish-turn the large outside diameter. These tools are seen in the illustration just after they have been indexed into line with the work. While the cuts are being taken by the tools on the third turret face, a tool on the front cross-slide is fed forward to finish-face the flange.

Tools on a slide mounted on the fourth turret face are then used for finish-facing the hub end of the brake-drum in the same manner as the tools used for rough-facing, except that the tools are mounted in the opposite direction to the rough-facing tools and are fed sidewise by a bar on the front cross-slide. The outer corner of the hub bore is also chamfered. The complete machining of the brake-drums is accomplished in twenty minutes.

Cutting External Screw Threads with Dies

The common methods of cutting external screw threads are: (1) By means of a single-point tool as in a lathe; (2) by means of a die; (3) by milling either with a single or a multiple cutter; (4) by grinding (which is a true cutting operation even if the chips are minute). The method of cutting a screw thread on any given class of work is determined by considering such factors as related operations, quantity required, and degree of accuracy. This section does not deal with the use of the lathe because this subject is covered in many treatises on shop practice.

When thread-cutting is the only operation required, power-driven threading machines equipped with dies are commonly employed. For example, if the operation is simply that of threading the ends of bolts, studs, rods, etc., a threading machine or "bolt cutter" would generally be used, but if cutting the thread were only one of several other operations necessary to complete the work, the thread would probably be cut in the same machine performing the additional operations. For instance, parts are threaded in turret lathes and automatic screw machines by means of dies and in conjunction with other operations. When screws are required which must be accurate as to the pitch or lead of the thread, and be true relative to the axis of the work, a lathe or a thread milling machine is generally used. Such machines are also employed, ordinarily, when the threaded part is comparatively long and large in diameter. Many threads which formerly were cut in the lathe are now produced by the milling process in special thread-milling machines. The method often depends upon the equipment at hand and the number of parts to be threaded. Very precise threads may be produced by grinding.

Example of Thread Cutting on Die Type of Machine.— The application of a threading machine equipped with a die is illustrated in Fig. 1. This particular machine is for cutting threads of 7/16-inch diameter, fourteen per inch, American Standard coarse thread series, to a length of 5 1/2 inches. The work-piece is a special aluminum-alloy stud, 6 inches in length. One end is held between jaws on the carriage, and the part is threaded as the carriage advances the other end through the chasers of the die-head on the headstock. The movement of the carriage is controlled by a lead-screw. Some machines are equipped with a lead-screw so that the carriage will have a positive feeding movement when a thread is being cut, in order to prevent inaccuracy in the pitch of the thread. When a machine does not have a lead-screw, the feeding movement of the carriage is derived from the action of the dies upon the thread being cut. This method of feeding may be satisfactory when cutting such threads as the United States Standard, the V-thread, or a Whitworth thread. When cutting square threads, however, or those of special form, or when threading long work where the cumulative error becomes important, a lead-screw is necessary. This machine shown in Fig. 1 has a capacity for cutting, on a production basis, threads from 1/4 inch to 1 1/2 inches in diameter to the Class 3 fit demanded for aircraft parts.

Another threading operation which consists of cutting a No. 10 thread, thirty-two per inch, American Standard fine series, on a chromium-molybdenum-steel bolt is shown in Fig. 2. The bolt head is of rectangular shape, about 3/4 inch wide by 1 inch long, and of the same thickness as the bolt diameter. The bolt shank extends for a length of 3/4 inch. The rectangular head is held in the slotted end of a bar mounted in the tailstock chuck, the fit between the walls of the slot and the work being tight enough to grip the piece solidly.

Machine for Threading and Cutting Off Pipe.—The machine illustrated in Fig. 3 has a capacity for pipe from 1/8 inch to 2 inches. The illustration shows this machine threading one end of nipples, the unthreaded end of which

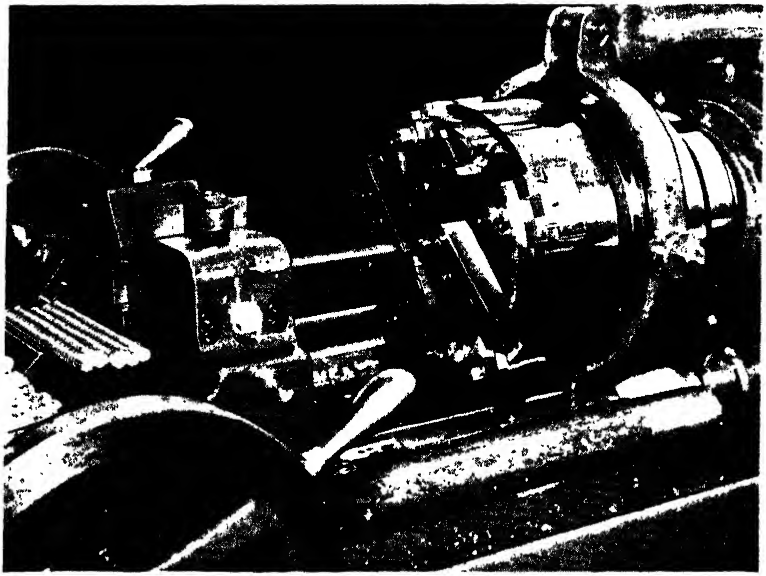

Fig. 1. Cutting Threads to a Class 3 Fit on a Threading Machine

Fig. 2. Cutting Thread on Chromium-molybdenum Steel Bolt

is later welded to steel plates. The cutting-off tool may be seen in back of the die-head. This machine is also equipped with a conical reaming tool mounted on a holder that can be moved along the rear cylindrical bar on which the die-head carriage slides. The reamer can be applied to the end of a pipe, after the die-head has been withdrawn to the end of the machine opposite the headstock, by swinging the reamer into line with the center of the pipe and then pushing it against the end of the pipe.

Cutting Thread on 6-Inch Pipe.—A large pipe thread-

Fig. 3. Threading and Cutting Nipples on a Machine that has a Capacity for Handling Pipe Ranging from 1/8 Inch to 2 Inches

ing and cutting machine is shown in Fig. 4. At the time that the photograph was taken, this machine was engaged in cutting the thread on a 6-inch pipe for a fuel-oil suction line required on board ship. The machine is equipped for handling pipe from 2 1/2 inches to the size shown.

In cutting threads, the pipe is gripped firmly and rotated by means of the chucks at the front and back ends of the headstock. The threads are cut by a die-head on a carriage at the right-hand end of the machine which is fed toward the work. In Fig. 5 is shown the opposite side of the die-head carriage, which is equipped for cutting off pipe to the required lengths and "reaming" the ends of pipe on the inside to a bevel. For the cutting-off operation, use is

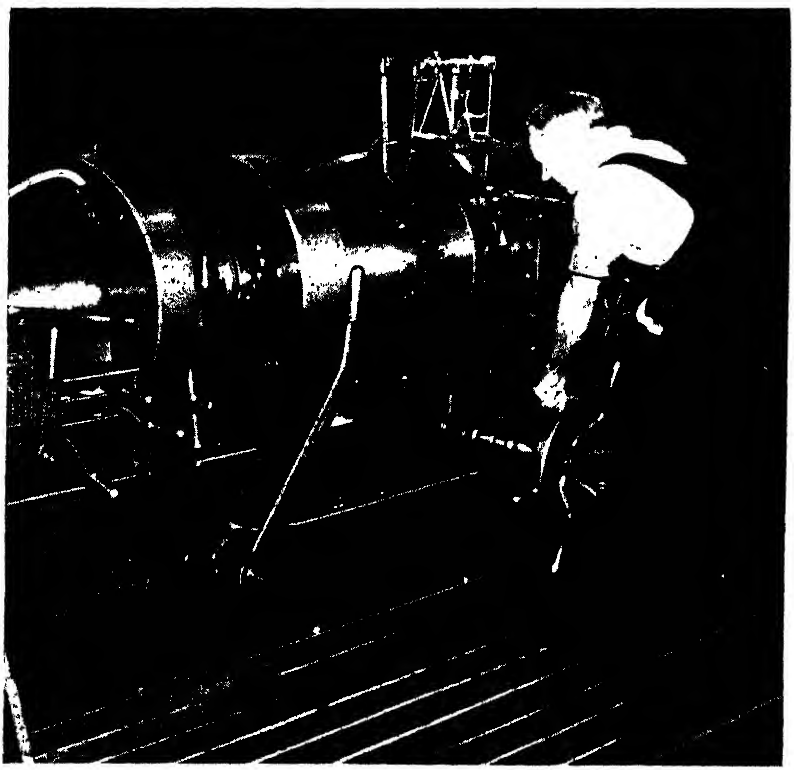

Fig. 4. Pipe Threading and Cutting Machine Engaged in Cutting the Threads on a 6-inch Pipe

made of a tool on a slide that is fed horizontally toward the pipe, while in reaming, the tool in front of the cutting-off tool is used, the reaming tool being mounted on a lever that can be swung forward to bring the tool in contact with the end of the pipe. In both cutting-off and reaming, the pipe is rotated by the same chucks as are employed in threading.

Multiple-spindle Threading Machines. — Threading machines having two or more spindles are used in preference to the single-spindle type where large quantities of bolts, etc., are to be threaded constantly. These machines operate on the same general principle as the single-spindle design. The spindles are parallel and each one has an inde-

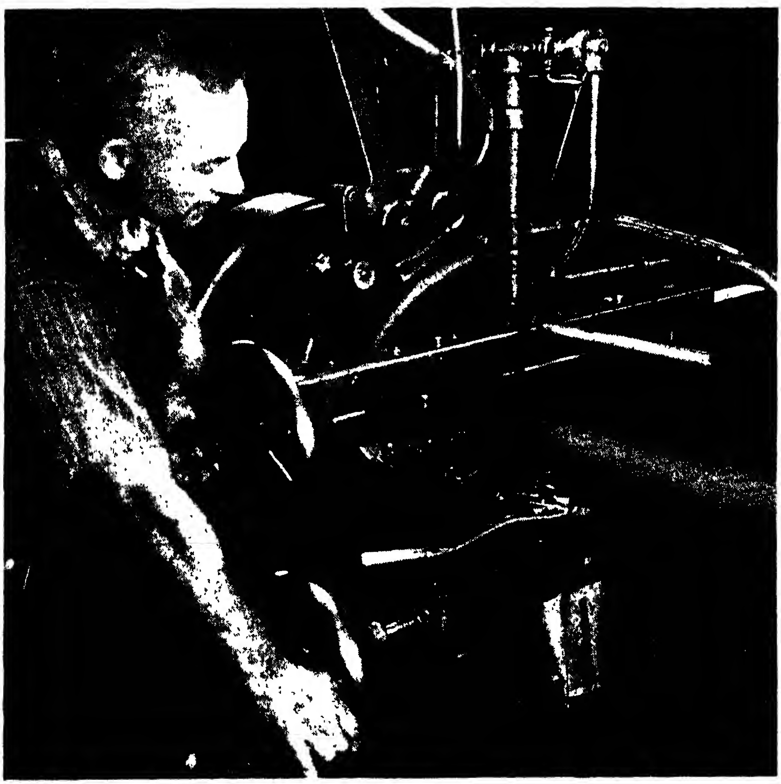

Fig. 5. End of Machine shown in Fig. 4, used for Cutting-off and Reaming

pendent carriage and vise so that, while a thread is being cut on one bolt or other part, another bolt is being inserted in or removed from the vise of the other carriage.

The double-spindle threading machine shown in Fig. 6 threads the shank ends of the pins shown for a length of 1 3/8 inches. The threads are 1 inch in diameter, 14 per inch, and of American Standard form. They must pass pitch-diameter thread gages of 0.9500 and 0.9536 inch. The work is held in carriage jaws that are shaped to the contour of the elliptical head of the pin. Swinging stops at the front and back of the machine are used to locate the front end of the pieces, these stops being swung out of the way of the die-head chasers before the operation is started.

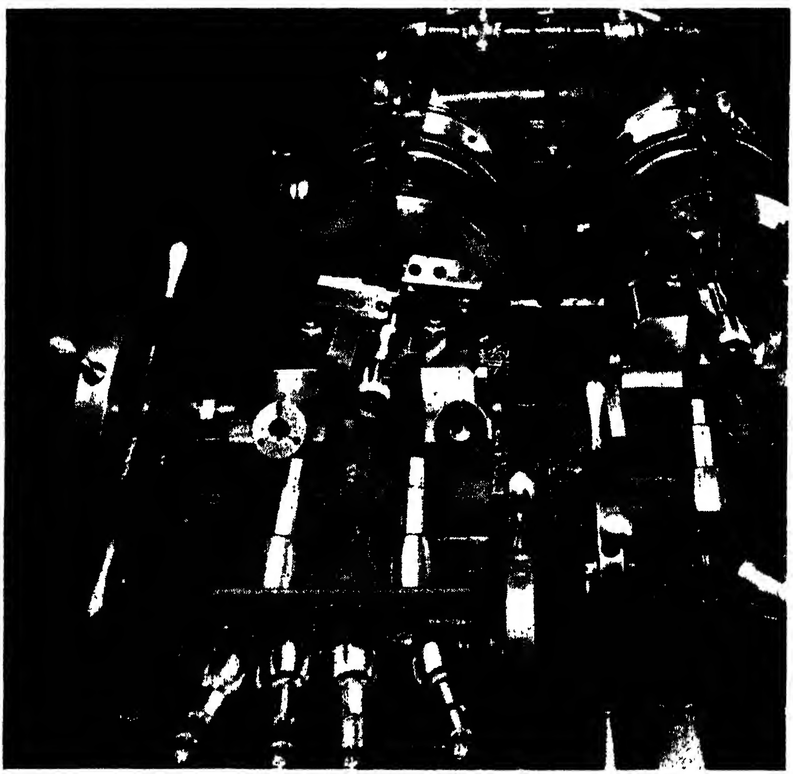

Fig. 6. Two-spindle Machine Equipped for Cutting Threads on Shank End of Torque-rod Pins

Cutting Threads Close to a Shoulder with Self-opening Die-heads.— Specifications often call for a thread that is too close to a shoulder to permit it to be cut on a practical production basis. Even a small increase in the width of the "neck" or clearance space adjacent to the shoulder may be very helpful. In some cases, the tapped hole has been counterbored or a washer placed under the head of the screw; in others, the use of a finer pitch thread has solved the problem. In the case of a part with no neck, the chamfer of the chasers has often been lengthened to produce a smoother cut; and while this brought the last full thread farther from the shoulder than was originally called for on the drawing, the change has been permitted. The following information on this general subject is from an article in MACHINERY by G. E. Mager.

The question as to how close to a shoulder a full thread can be cut with practical equipment depends largely upon the material to be cut, how smooth a thread is required, whether the pitch is coarse or fine, and whether the diameter of the shoulder is small or large. It is well to remember that, when die chasers are purchased, they usually have the chamfer angle ground to a "short throat." This chamfer angle will take in a length of about one and one-half to two threads on pitches of, say, 16 and finer. On coarser pitches, up to, say, 8 pitch, the "short throat" chamfer will probably take in as much as two or two and one-half threads. These figures will vary somewhat with the products of different manufacturers, but are close enough to show what are considered the shortest chamfers that will cut well enough on screw stock to test chasers for accuracy in lead, thread form, etc. Short-chaser chamfers will not usually cut smooth threads on the tough or hard alloys so extensively used today, such as S A E 2330, 3140, etc. Some of the softer materials—such as S A E 1010 and 1020, etc. —also cannot be cut smoothly with short-chamfer chasers.

A threading neck is only as wide as its narrowest measurement; but it is satisfactory, if needed, to put a radius next to the head, provided it is not greater than the length of the chamfer on the chasers. The corner of the necking

tool should be slightly broken, but not rounded, where the last thread ends, as this would be equivalent to making the neck narrower. A bevel where the thread ends should be formed to reduce the thin fin and burrs that usually curl in toward the neck. The angle of this bevel is often made 30 degrees, but in aviation work 45 degrees is frequently used to further reduce burrs. This is essential when the screw is harder than the material it goes into, in order to prevent the burrs from damaging the threads in the softer material. Although the threads shown in the accompanying diagrams appear to be of the sharp V-type, they also represent threads of the American National or U. S. form.

A die-head cannot be expected to open exactly at the point of "just reaching" a shoulder. Therefore, a little more room than the chaser-chamfer length must be added to allow time for the action of the head to open; and if the pitch of the thread is coarse, the shoulder on the work is large in diameter, or threads are cut close to a chuck, still more room is needed to prevent a jam from a chip getting wedged between the shoulder and chasers or between the chuck jaws and the chasers.

In cases where it is decided that a part cannot be satisfactorily designed without having the thread cut close to a shoulder, and it is agreed that the factory must do the job the best it can, regardless of extra trouble and expense, the following suggestions may prove helpful. Keeping the outside diameter of the work to, or near, the allowable low limit in all threading is usually good practice, and particularly important in close-to-shoulder threading, as it makes it unnecessary to start the chaser chamfer below the outside diameter of the thread, thereby keeping the chamfer as short as possible. It is necessary, in some cases, to use two dies where close-to-shoulder threads are called for and a smooth thread is required. The chasers in the first die are ground with a long chamfer for cutting a smooth thread, while the second die, which follows over the first cut, has chasers of short chamfer to extend the cut of a full thread where the first chasers left off.

In threading close to a chuck, it is best to use extension

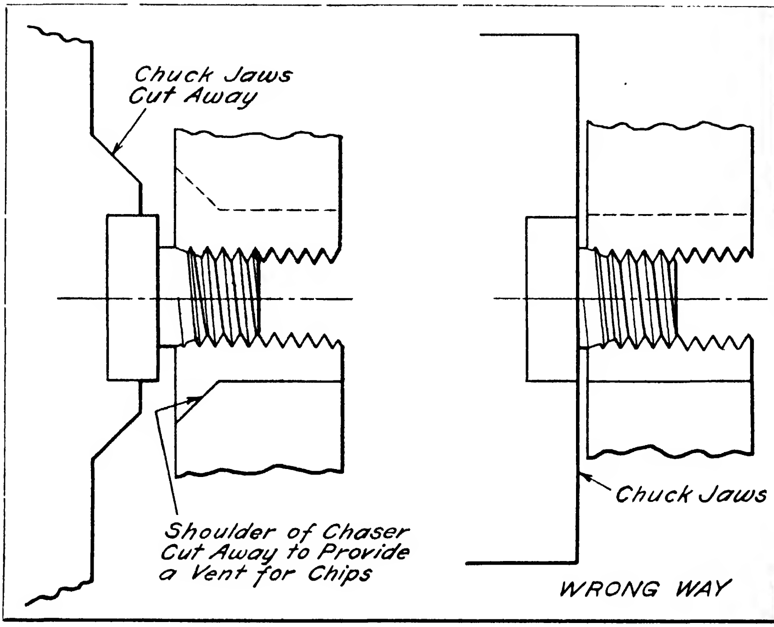

Fig. 7. (Left Diagram) Chuck Jaws and Chasers Cut Away to Provide Proper Chip Clearance. (Right Diagram) Lack of Chip Clearance Such as Shown Here often Results in Damaged Chasers

jaws or holders to provide as much chip room as possible. The outside diameter of the extensions should be as small as is consistent with the strength required to hold the work satisfactorily. The jaws should also be cut away, as shown in Fig. 7, left diagram. When the chip is long and stringy, the shoulders on the chasers are sometimes ground away to provide clearance for such chips.

The right diagram shows a typical troublesome condition. Here the work, which is to be threaded close to a shoulder, is set too far back in the chuck and the chuck jaws are not extended. The danger of the chasers striking the shoulder or chuck jaws, or a chip wedging between them, is ever present. A screw with a small head requires less chip room than a screw with a large head. A head might be considered large when the diameter is greater than standard for that size screw.

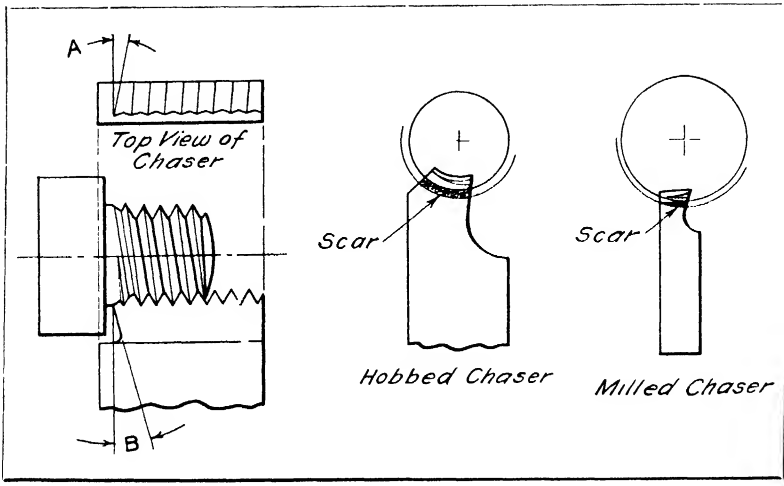

Fig. 8. (Left Diagram) Chaser Ground to Give Chip Clearance to Help in Threading Close to a Shoulder. Diagrams at Right Show how Chasers are Scarred by Striking Shoulder on Work

A good way to grind chasers required for threading work close to a shoulder is illustrated in Fig. 8 (see diagram at left), which shows how stock can be removed or cut away from the ends of the chasers to provide more chip room. Angles *A* and *B* can be, say, 5 to 10 degrees. Angle *A* helps to lessen damage to the chaser if it strikes the shoulder slightly. When chasers are seen with teeth that have been chipped off by striking a shoulder, the evidence is usually there in the form of a scar where the chasers hit the shoulder, as indicated by the hobbed and milled chaser diagrams at the right in Fig. 8.

In addition to the usual pull-off trip, an ingenious device consisting of a front-end trip has done much to prevent chasers from striking a shoulder, and is especially desirable when cutting very short threads. An adjustable stud is attached to the machine with which the front-end trip makes contact. This trips the die-head. The check-nut on the end of the trip provides for fine adjustment, and can be set to open the head when the chasers are run close to the shoulder, without danger of their striking.

Milling External and Internal Screw Threads

There are two general methods of forming screw threads by milling, which may be designated as the single-cutter and the multiple-cutter methods. Whenever a single cutter is used, the axis of the cutter is inclined in order to locate the cutter in line with the thread groove at the point where the cutting action takes place. The lengthwise traversing movement, equal to the lead of the thread per work revolution, is applied to the cutter on some machines and to the screw being milled on other machines. The single-cutter process is especially applicable to the milling of large screw threads of coarse pitch and the heavier classes of work. For fine pitches and short threads, the multiple-cutter method usually is preferable because it is more rapid. The object of using a multiple cutter instead of a single cutter is to finish a screw thread complete in approximately one revolution of the work. In order to finish the thread complete in one revolution (plus a slight amount of over-travel), it is necessary to use a cutter which is at least one or two threads or pitches wider than the thread to be milled. In using a multiple cutter it is simply fed in to the full thread depth and then either the cutter or screw blank is moved in a lengthwise direction a distance equal to the lead of the thread.

Multiple-thread milling cutters have formed teeth so that they may be sharpened by grinding the front faces without changing the tooth form. These multiple cutters should not be used ordinarily for external threads having helix angles above 3 1/2 degrees or for internal threads above 2 1/2 degrees.

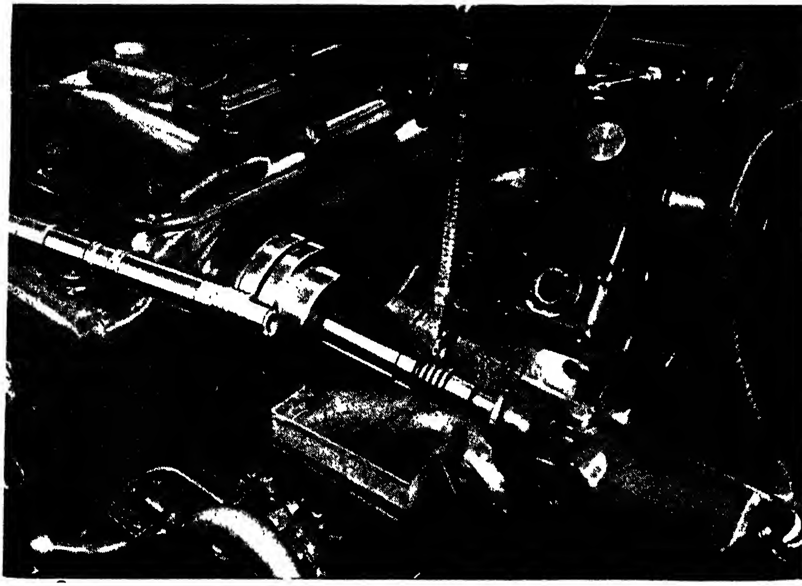

Fig. 1. Milling Thread on Machine Gun Barrel

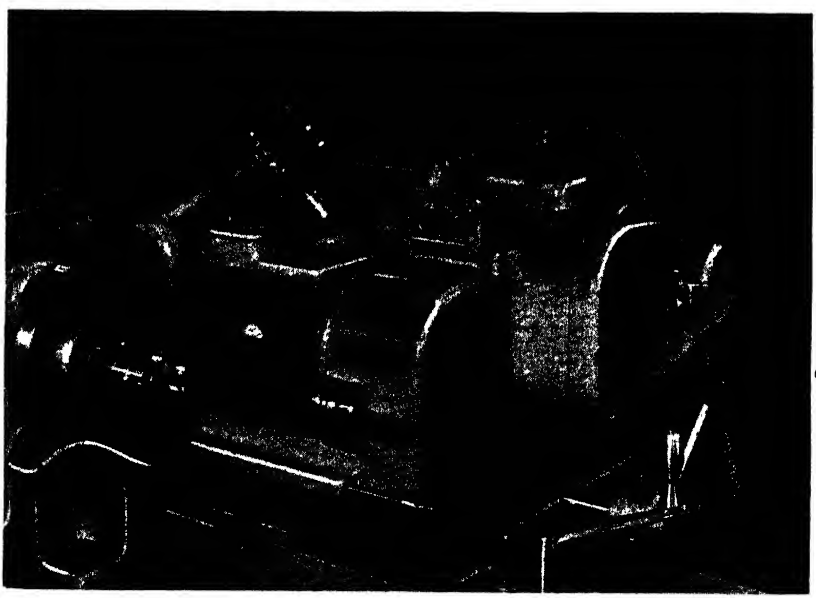

Fig. 2. Thread Milling with Multiple Cutter

Examples of Thread Milling on Single-cutter Type of Machine.— Fig. 1 illustrates the application of a single-cutter type of machine. The operation is that of milling a thread on the end of a machine-gun barrel. This is done after the rifling operation is completed. The thread is left-hand, of square style, with slight fillets at the root, and of 0.2756 inch pitch. The diameter at the root is 1.114 inches within limits of minus 0.006 inch, plus nothing. The groove width is from 0.140 to 0.145 inch.

Milling Thread with Multiple-cutter Type of Machine.— Another thread milling operation on a machine gun barrel is shown in Fig. 2. This thread is milled on the breech end after the barrel is reamed. The gun barrel is held accurately for this operation in a long chuck into which it is loaded from the left-hand end of the headstock. The barrel is gripped in a collet chuck at the front end of the headstock and located in a bushing near the rear end. The thread is milled in about one revolution of the barrel.

The lead of the thread is controlled by means of a cam in the base of the machine, and must be true within 0.0004 inch. The tolerance on the pitch diameter of 15/16 inch is 0.0036 inch. Wooden trays and tables are provided on practically all the machines used in barrel operations, so as to guard against damage to the work.

Milling Screw Threads and Adjacent Cylindrical Surfaces.—The milling of a thread and of a plain cylindrical surface in front of the thread, on the breech end of a rifle barrel, are accomplished simultaneously in the thread milling machine illustrated in Fig. 3. The tolerance on the plain diameter is only 0.001 inch, while a tolerance of 0.0045 inch is allowed on the pitch diameter of the threads, of which there are twenty per inch. The long rifle barrel is inserted into the chuck through the hollow headstock spindle. A multiple type of thread milling cutter is used; hence, the operation is completed in about one revolution of the work.

Milling Internal Threads.—Fig. 4 shows internal threads being milled in a propeller shaft of an airplane engine. In

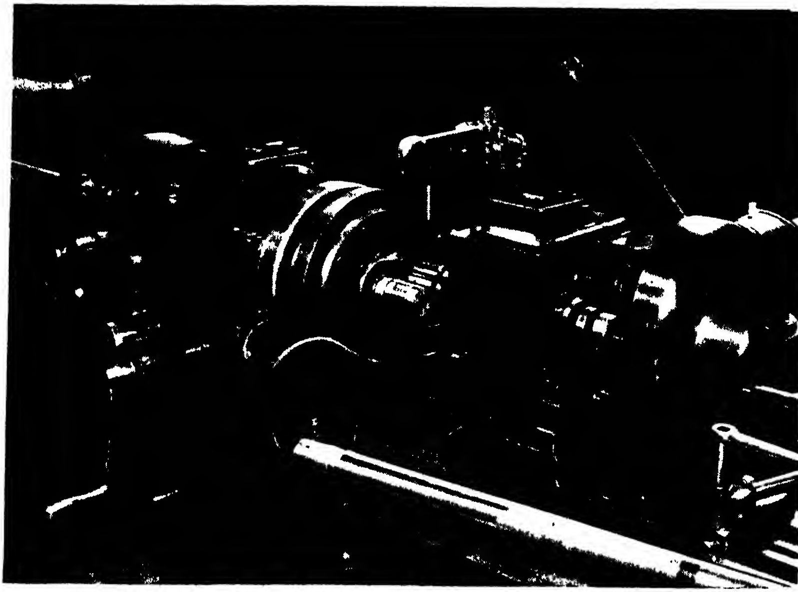

Fig. 3. Milling a Thread and also a Plain Cylindrical Surface

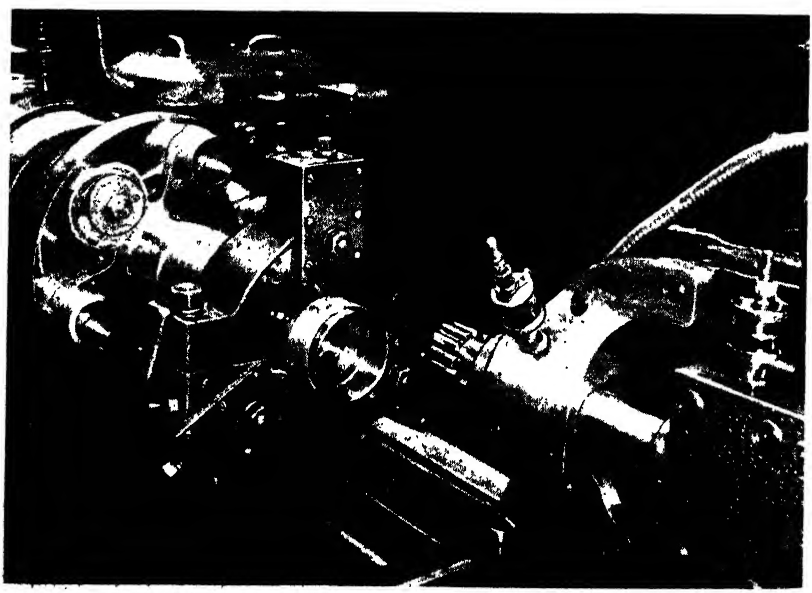

Fig. 4. Internal Thread Milling on Airplane Propeller Shaft

the operation shown, the thread has a nominal diameter of 2 7/8 inches, and there are sixteen threads per inch. The "Go" gage dimension for the pitch diameter is 2.8344 inches and the "Not Go" gage dimension, 2.8376 inches. In addition to the thread, the cutter finishes a plain surface, 1/2 inch wide, in front of the thread.

Milling External Thread on Planetary Type of Machine.— External threads are produced on the cylinder barrels of Diesel engines by employing the planetary type of milling machine shown in Fig. 5, which is equipped with eighteen form cutters arranged around a circular path on a holder mounted on the headstock spindle. In this operation, the cylinder barrel is slipped on a split sleeve, so as to insure accurate relation of the threads to be cut with the ground

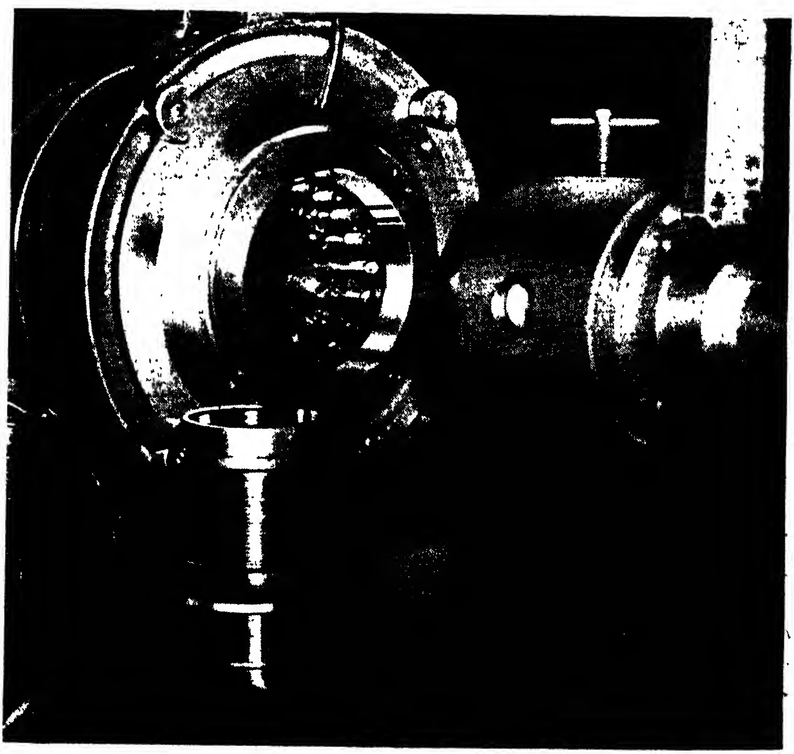

Fig. 5. External Thread Milling on Planetary Type of Machine

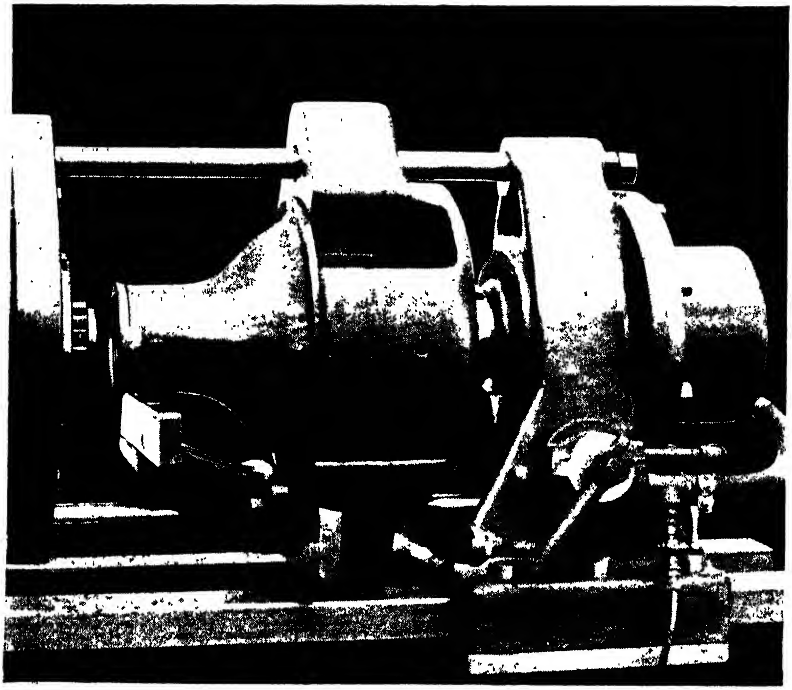

Fig. 6. Milling Thread in the Propeller-shaft Bore of Differential Carrier

cylinder bore. The split sleeve is contained within a fixture that advances the work into the operating position through the action of a hydraulic cylinder and withdraws it upon the completion of the cut. The work remains stationary while the form cutters rotate eccentrically around it to mill the thread, as is conventional practice with this type of machine. The front end of the work-carrier is made with a taper nose to fit a taper seat on the headstock fixture on which the tools are mounted, thus insuring accurate location of the work in relation to the cutters. The pitch diameter of the thread produced must be between 5.4874 and 5.4895 inches. There are twelve threads per inch for a width of 1 1/64 inches.

Milling Internal Thread on Planetary Type of Machine.— The planetary type of machine illustrated in Fig. 6 is

equipped for milling threads in the propeller-shaft bores of differential carriers. Before this method was adopted, considerable difficulty was experienced in cutting the threads true with the center line of the bore, as the work was readily distorted.

The malleable-iron differential carrier is mounted on a vertical surface plate which is connected to an air cylinder at the right-hand end of the machine. With the surface plate drawn away from the head of the machine, as shown, the differential carrier is loaded in position for chucking. Air is then applied in the air cylinder to move the surface plate and work forward over the revolving thread milling cutter and to locate the left-hand end of the casting in a hardened and ground taper ring provided in the faceplate of the machine. This method of chucking insures rigid

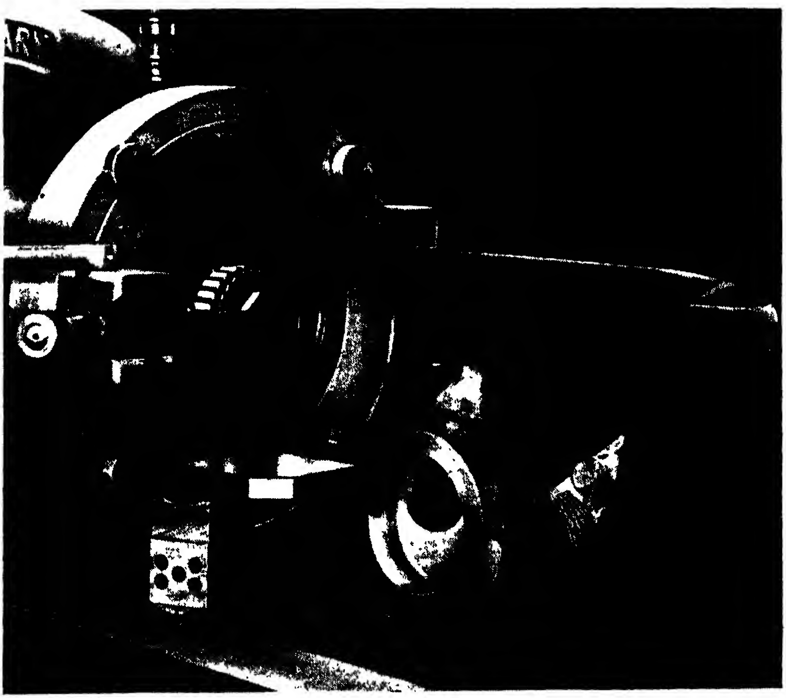

Fig. 7. Milling Threads and a Plain Cylindrical Surface in Airplane Engine Cylinder Heads

holding of the work. The threads are milled within a tolerance of plus or minus 0.001 inch in 30 seconds floor-to-floor time.

Milling Internal Thread and Bore Simultaneously.— Cylinder heads for airplane engines have the large bore milled and threaded simultaneously on the planetary machine illustrated in Fig. 7. Both the threads and the bore must be machined within close limits of accuracy, the over-all tolerance on the pitch diameter of the threads being only 0.001 inch. The bore must be finished within the same tolerance in relation to the pitch diameter of the threads.

From the illustration it will be observed that the thread milling cutter and the bore finishing cutter are made integral. The cylinder head is located from an external surface turned around the face, which is seated in a locating ring in the head of the machine. A swinging clamp holds the cylinder head rigidly to the locating ring when the milling cutter automatically moves off center to cut the threads and the bore surface to the proper depth and then makes its planetary movement around the inside of the work. The threads and bore are milled in one revolution of the cutter.

Grinding Screw Threads

Thread grinding is applied both in the manufacture of duplicate parts and in connection with precision thread work in the tool-room. In grinding a thread, the general practice in the United States is to use a large grinding wheel (for external threads) having a diameter of possibly 18 to 20 inches. The width may be 5/16 or 3/8 inch. The face or edge of this comparatively narrow wheel is accurately formed to the cross-sectional shape of the thread to be ground. The thread is ground to the correct shape and lead by traversing it relative to the grinding wheel. This traversing movement, which is equivalent to the lead of the screw thread for each of its revolutions, is obtained from a lead-screw. The wheel shape is accurately maintained by means of diamond truing tools. On one type of machine, this truing is done automatically and the grinding wheel is also adjusted automatically to compensate for whatever slight reduction in wheel size may result from the truing operation.

An internal thread may also be ground with a single-edged wheel. The operation is the same in principle as external thread grinding. The single-edged wheel is used whenever the highest precision is required, grinding the work either "from the solid" or as a finishing operation. On some classes of work, the thread is formed entirely by grinding "from the solid," especially if the time required is less than would be needed for a rough thread-cutting operation followed by finish-grinding after hardening. Grinding threads from the solid is applied to the finer pitches. In some plants, threads with pitches up to about 1/16 inch are always ground by this method.

Examples of Thread Grinding on Single-wheel Type of Machine.—The single-wheel type of thread grinding ma-

chine may be used for grinding threads on a large variety of parts. The Acme-thread tap lying on the top of the tail-stock (see Fig. 1) and on the worm lying on the headstock were ground "from the solid." The tap is 1 3/8 inches in diameter and has three threads per inch. It was ground to diameter, pitch, form, etc., within a tolerance of 0.0001 inch, about six passes of the tap across the grinding wheel being required to complete the job. In front of the worm is seen a traversing screw for an anti-aircraft machine gun sight which has a threaded length of 11 1/2 inches. These threads are 1/2 inch in diameter, and are held to form, pitch diameter, etc., within 0.0005 inch. They are produced with three passes across the wheel.

Grinding Buttress Thread on Airplane Engine Cylinder Barrel.— The application of a precision thread grinding machine for grinding a modified buttress thread on one end

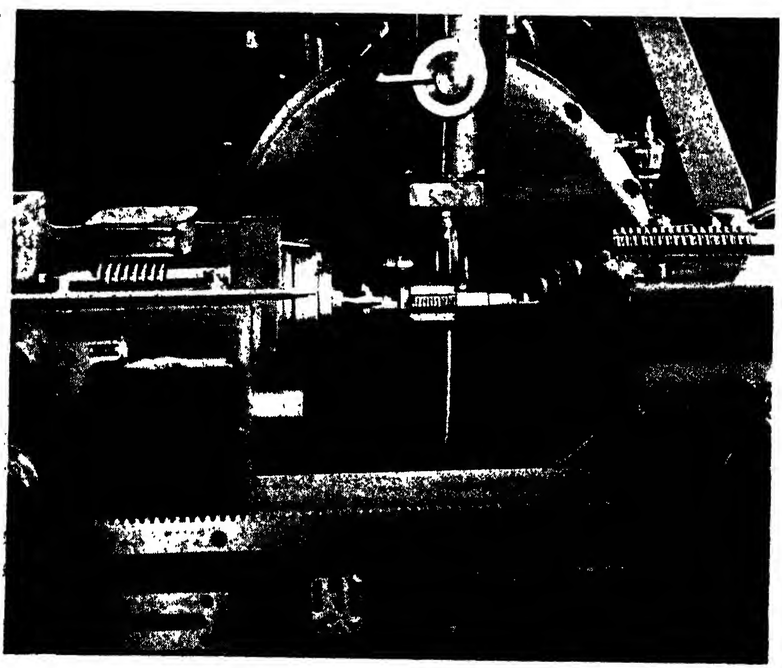

Fig. 1. Grinding Screw Thread on Machine of Single-wheel Type

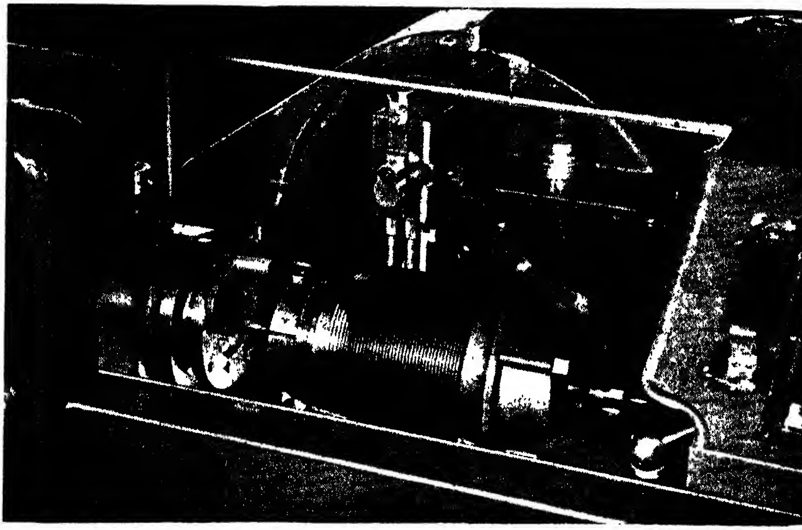

Fig. 2. Grinding Buttress Thread on Engine Cylinder Barrel

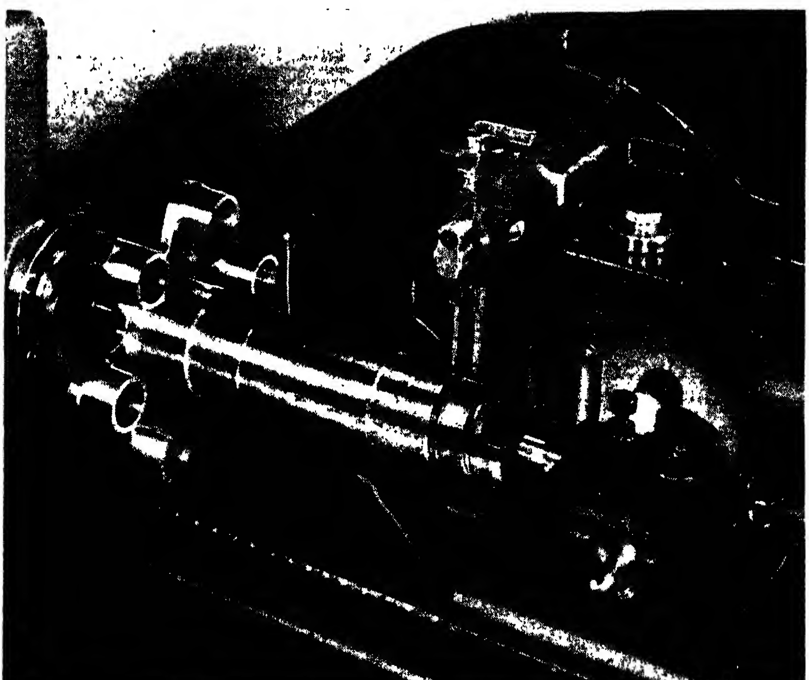

Fig. 3. Grinding Threads from the Solid

of cylinder barrels is illustrated in Fig. 2. The thread is ground to a pitch diameter of 6.493 inches and is 0.940 inch long. The depth is 0.0903 inch, and the pitch 0.1676 inch. The thread has a load-resisting flank angle of 7 degrees 30 minutes, and a thread angle of 45 degrees, the tops of the thread being rounded to a radius of 0.035 inch, and the bottoms to a radius of 0.015 inch. In this operation, the tolerance on the pitch diameter is only 0.0015 inch, and the lead tolerance is plus or minus 0.0002 inch. There can be no appreciable variation in the radii or thread form.

Grinding Thread of Propeller Shaft.—Threads are ground on an aircraft propeller shaft by means of the precision thread grinder shown in Fig. 3. The threads are ground from the solid on two surfaces of the shaft, the thread in one case being 3 15/16 inches diameter by 1 inch long, and in the other case, 3 7/16 inches diameter by 9/16 inch long. These threads are 12 per inch and of United States or American Standard form. The propeller shaft is of S A E X4340 steel, and is hardened to from 290 to 321 Brinell prior to the thread-grinding operation.

Grinding an Internal Thread.—Fig. 4 shows a thread-grinding machine being used for grinding an internal thread in a thin rim of comparatively large diameter on the end of a clutch barrel for airplane engine starters. This rim is less than 1/8 inch thick and, in addition, has a slot 1/4 inch wide extending from the end for a length of approximately 1/2 inch. A thread is also ground on the outside of this ring.

The pitch diameter of the internal thread is held to between 3.0043 and 3.0066 inches, the thread being of American Standard form, twenty-four per inch. The external thread must be held within a comparable tolerance. The thin wall and the slot made it practically impossible to finish these threads to the required accuracy until they were produced by grinding, due to the distortion which resulted from heat-treating the part after the threads had been cut. Thread grinding was adopted because it permits the threads to be ground from the solid after hardening,

and distortion is, therefore, avoided. Fig. 5 shows the large diameter external thread being ground.

In addition to the internal and external threads on the large end of this part, threads of twenty-four per inch are also ground on the 9/16-inch diameter stem that is seen extending from the chuck end in Fig. 5. The part is a nickel-chromium-steel forging. All of these threads are ground in two passes of the wheel, from 0.005 to 0.006 inch of stock being left for the finish-grinding. The wheel is dressed between the first and second passes. The finished threads are inspected by means of "Go" and "Not Go" gages.

Grinding Threads with Multi-edge Wheel. — An entire screw thread, if not too long, may be ground completely in one revolution by using a multi-edge type of grinding wheel. The face of this wheel is formed of a series of an-

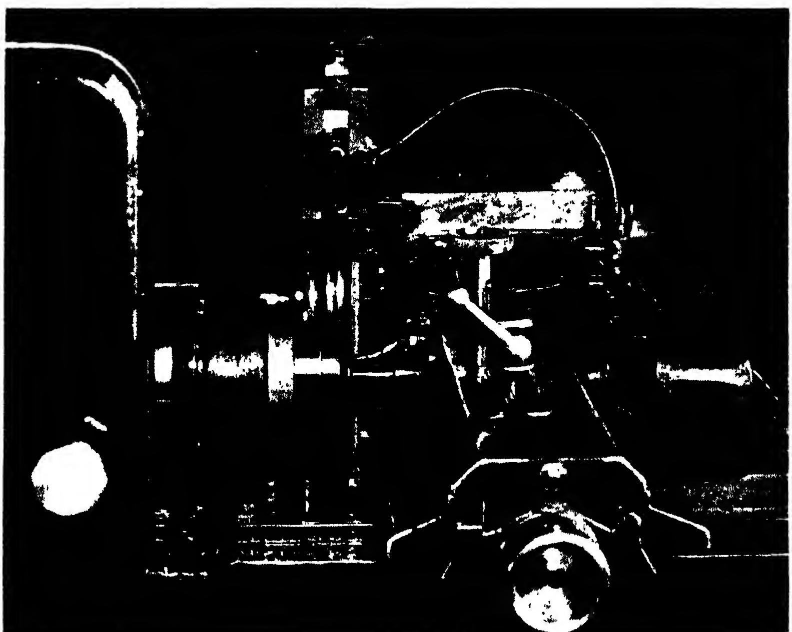

Fig. 4. Grinding an Internal Thread on a Clutch Barrel for Airplane Starters after Hardening to Obtain High Degree of Accuracy

nular thread-shaped ridges so that it is practically a number of wheels combined in one. The principle is the same as that of milling screw threads by the multiple-cutter method. If the length of the thread to be ground is less than the width of the wheel, it is possible to complete the grinding in practically one work revolution as in thread milling. A grinding wheel having a width of, say, 2 1/2 inches, is provided with annular ridges or threads across its entire width. The wheel is fed in to the thread depth, and, while the work makes one single revolution, the wheel moves axially a distance equal to the thread lead along the face of the work. Most threads which require grinding are not longer than the width of the wheel; hence, the thread is completed by one turn of the work.

If the thread is longer than the wheel width, one method is to grind part of the thread and then shift the wheel

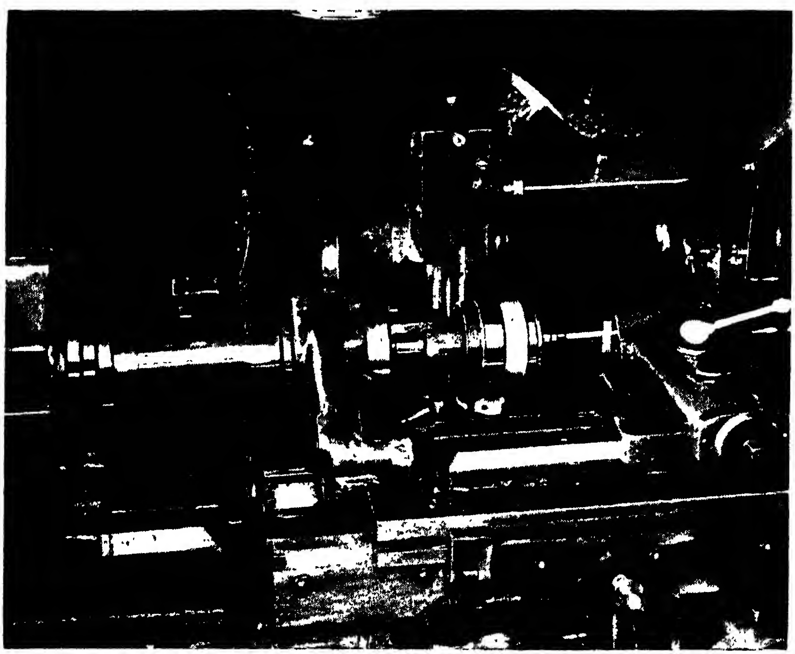

Fig. 5. Grinding an External Thread on Outside of Clutch Barrel Rim

axially. A second method is that of using a multi-edge tapering wheel which is fed axially along the work. The taper is to distribute the work of grinding over the different edges or ridges as the wheel feeds along.

Plunge-cut Method of Grinding Threads with a Multi-edge Wheel. — The plunge-cut grinding method with a multi-edge wheel may be used in preference to a single-edge wheel, for more rapid production when extreme accuracy is not required, but a good thread surface is wanted, and when the material is difficult to cut by other means. The grinding wheel may be up to 2 1/2 inches wide, being provided with annular grooves or threads for its entire width. The wheel is brought up against the work, and while the work makes a single revolution, the wheel is fed the distance of the thread lead axially along the face of the work. Most threads required to be ground for production purposes are not any longer than the width of the wheel; hence, the thread is completed by one turn of the work. Some grinding machines have provision, however, for moving the grinding wheel along the work and "catching the thread," so that with a wheel 2 1/2 inches wide, a thread approximately 12 inches long can be ground in five successive steps.

The accuracy claimed for grinding with a multiple-edge wheel is approximately as follows: Pitch diameter, plus or minus 0.0004 inch; pitch angle, plus or minus 8 minutes; error in lead not over 0.0004 inch in 1 1/2 inches. These tolerances are sufficient for most machine parts.

The multi-edge grinding wheel is dressed by means of an oil-hardened cylindrical carbon-steel roller having annular ridges of the exact thread profile required. The roller is provided with spiral flutes, somewhat similar to those of a gear-cutting hob. It is mounted in bearings in a fixture and produces the threads on the face of the grinding wheel by being pressed against the wheel while the latter is revolving slowly. At first sight, this method of obtaining a thread profile in the grinding wheel may appear to be an unsatisfactory procedure, but the results are surprisingly good, provided the wheels used are comparatively fine-

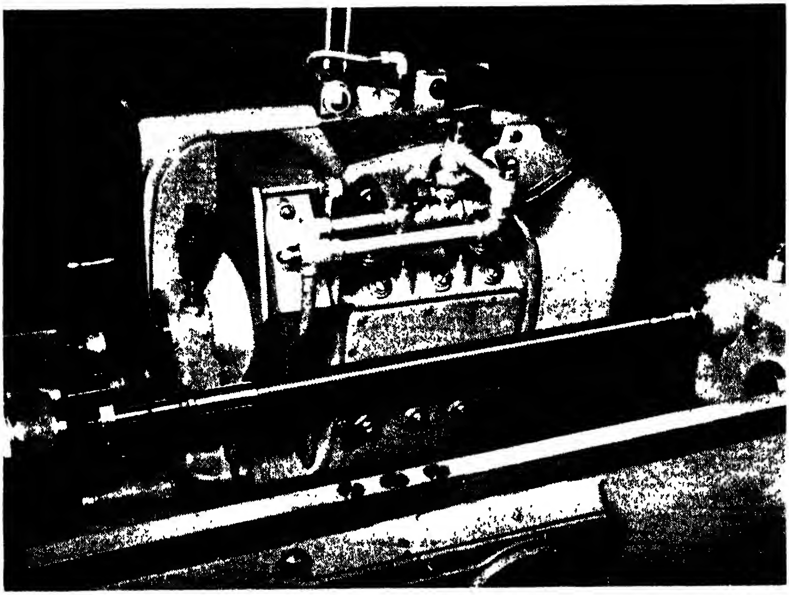

Fig. 6. Grinding a Hardened Lead-screw by Means of a Conical Multi-edge Wheel which is Traversed in an Axial Direction

grained with a dense texture. The grinding wheel revolves at about 150 revolutions per minute, driving the roller, which is free to turn and is simply pressed against the wheel. It requires, for ordinary pitches, only from about 2 1/2 to 3 minutes to press the thread grooves into a new wheel. Redressing can be done in about one minute.

It is obvious that this method of dressing a grinding wheel by means of a roller having the proper profile can be used not only for grinding threaded parts, but also when it is desired to shape the wheel for grinding profiles of various types. Many parts can be produced economically only in this manner.

Grinding Threads with Multi-edge Tapering Wheel.— A multi-edge tapered wheel that is fed axially along the work, is used especially for grinding long threads on shafts or spindles when it would be impracticable to use several steps with the plunge-cut multi-edge wheel. An example is shown in Fig. 6. The tapered grinding wheel is prac-

tically a series of single-edge grinding disks, each succeeding disk of a slightly larger diameter than the previous one, although, of course, all these "disks" are actually part of a single, solid, wide-faced wheel. Each "disk" has a comparatively light cut to take, and the method is, therefore, especially suitable for the grinding of long threads.

The tapered wheel is also employed for internal grinding. When used for that purpose, it is frequently cylindrical at one end, with the threads chamfered off at the other end in a manner somewhat similar to that used for a tap or a thread chaser. Such a wheel has been found to give the best results for internal threads when grinding from the solid. When extreme accuracy is required, the thread is finished by a single-point grinding wheel.

The accuracy obtained by the use of a tapered multi-edge wheel lies somewhere between that obtained by the use of a single-edge wheel and a plunge-cut multi-edge wheel.

Tapping with Single-Spindle and Multiple-Spindle Machines

Cutting screw threads in holes by means of taps is, of course, a very common operation that is required in manufacturing all types of machines or other mechanical devices. Because of this universal application, notable developments have been made both in the design of tapping machines and in the production of taps. In some cases, a single-spindle machine for tapping one hole at a time meets manufacturing requirements; in other cases, multiple-spindle machines are used. When large numbers of duplicate parts must be tapped, as in the automotive industry, a multiple-spindle machine may be designed expressly for tapping simultaneously all of the holes in a given part.

In tapping operations, the *tap,* as well as the machine, should be selected to suit the work to be done. There are three general classes of commercial taps. The least expensive has a cut thread or one not finished by grinding. A ground thread tap may have either a *commercial* ground thread or a *precision* ground thread. The latter is intended for work requiring the highest degree of accuracy obtainable by tapping. Cut thread taps made to American Standard specifications, when used under normal conditions, should, in the majority of cases, produce holes within Class 2 tolerances of the American Standard for screw threads. Ground thread taps made to these specifications, when used under normal conditions, should, in the majority of cases, produce holes within Class 3 tolerances of the American Standard.

General Features of Tapping Machines. — Machines designed especially for tapping or for drilling and tapping

holes are made in quite a variety of designs. Some of these machines are intended for one class of work, like the tapping of nuts, whereas others are adapted to tapping operations of a general nature; there are vertical and horizontal, and single- and multiple-spindle types. In tapping by power, the tap ordinarily is fed down into the hole to the required depth and its rotation is then reversed for screwing it out of the hole. There are different methods of obtaining this reverse motion. When the tapping is done in an ordinary drilling machine, special tap chucks are frequently used which are designed to reverse the rotation of the tap when the latter has reached the required depth. One form of tap-holding chuck is so arranged that the tap automatically stops when it strikes the bottom of the hole or when an adjustable depth gage comes against the top of the work. The raising of the spindle then reverses the tap which backs out at an increased speed.

Tapping machines also vary in regard to the mechanism for obtaining the forward and reverse motions of the tap spindle and the method of controlling these motions. A common arrangement for obtaining the two motions is by means of a clutch which is interposed between two pulleys revolving in opposite directions and is alternately engaged with these pulleys. The clutch may be controlled by (1) a hand-lever connecting with the clutch; (2) a foot-lever connecting with the clutch; (3) pushing the work and its fixture forward until contact is made with a stop-rod or lever which shifts the clutch for backing out the tap; (4) pushing the work against the tap while tapping and by pulling in the opposite direction for backing out the tap, the clutch being shifted by the direct thrust from the part being tapped and the resulting longitudinal motion of the tap spindles. The latter method is applied only to machines used for the lighter classes of work. The characteristic features of well-designed tapping machines are convenience of control and, for small tapping operations, a sensitive drive that will transmit enough power for operating the tap under normal conditions but not enough to break it in case the resistance to rotation becomes excessive.

Tapping with Single-spindle Machines. — The tapping of holes in the small irregular-shaped casting seen in Fig. 1 has been simplified by the provision of a simple box-type fixture, the principal purpose of which is to furnish a convenient holding means. The machine employed is a preci-

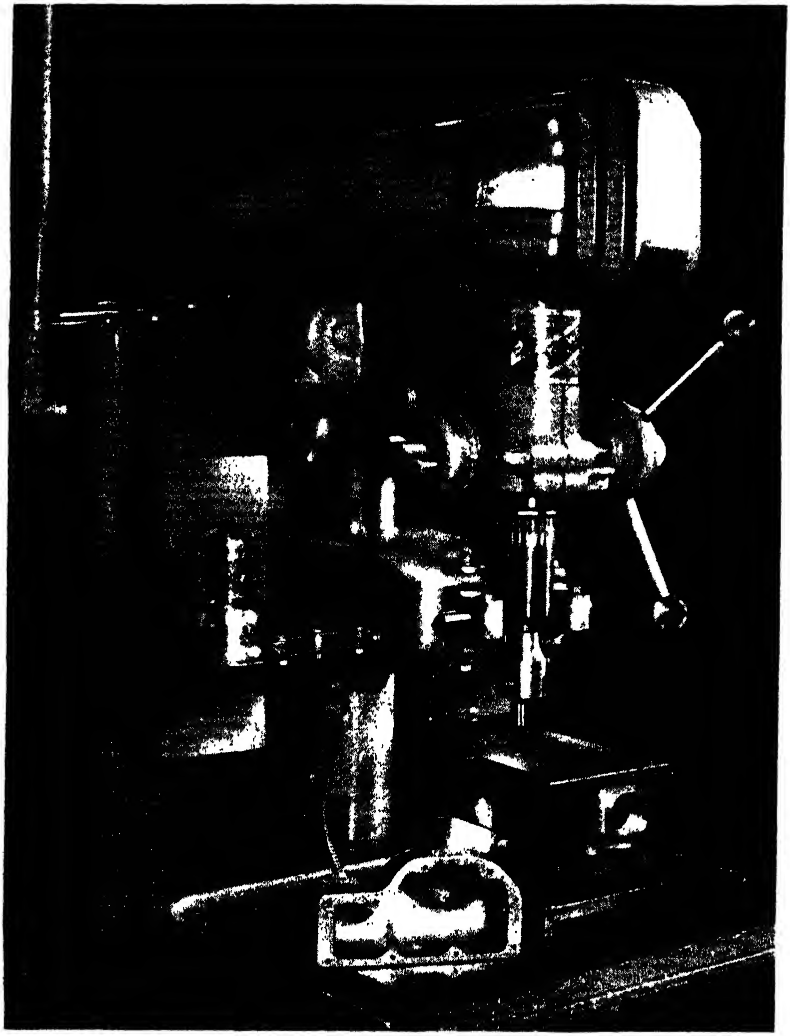

Fig. 1. Precision Tapping Operation in which an Irregular-shaped Part is Readily Handled by a Simple Jig

sion tapping machine, which is equipped with a lead-screw and guide fingers for controlling the feed of the tap from the start to the finish of the thread being cut. A No. 10 tap with thirty-two threads per inch is used, the threads being cut within the close tolerance customarily specified on aircraft work. Nine holes are tapped in the part.

The tapping operation illustrated in Fig. 2 consists of tapping fifty-four holes around the cylinder-sleeve contact

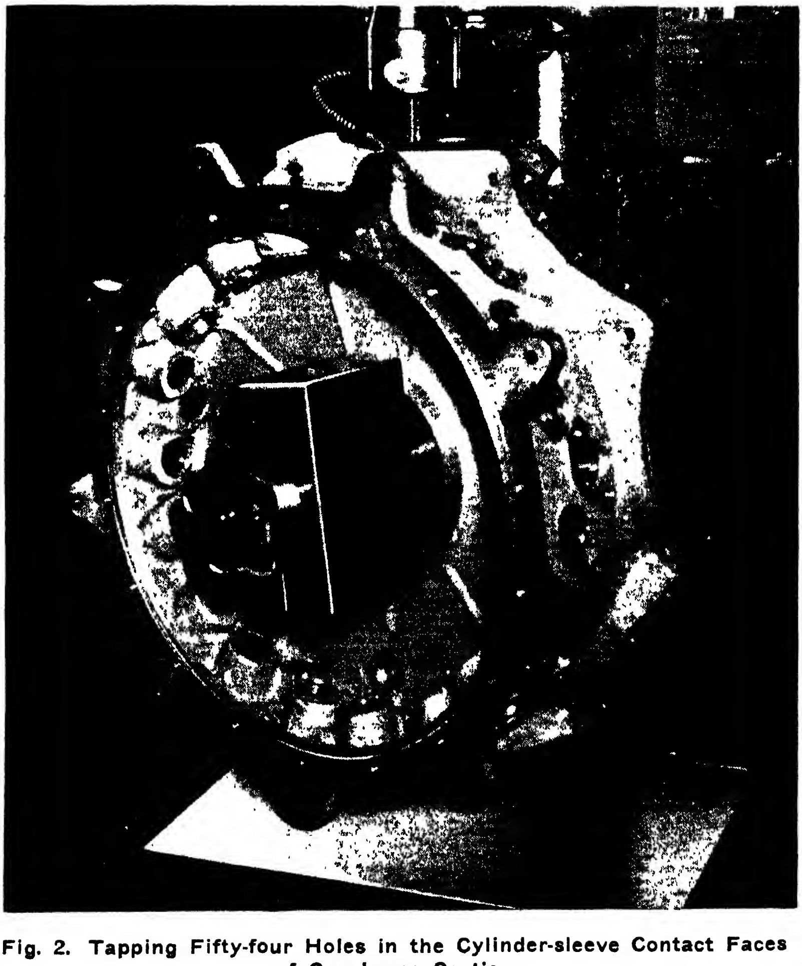

Fig. 2. Tapping Fifty-four Holes in the Cylinder-sleeve Contact Faces of Crankcase Section

faces of a crankcase section. Again a single-spindle tapping machine is used. The lead-screw and mating threaded plugs that control the feed of the tap into the work insure Class 3 fits of all holes tapped by the machine. Mounted at the front of this machine is a work-fixture provided with a large round plug at the upper end against which the half-bores for the cylinder barrels are successively clamped for

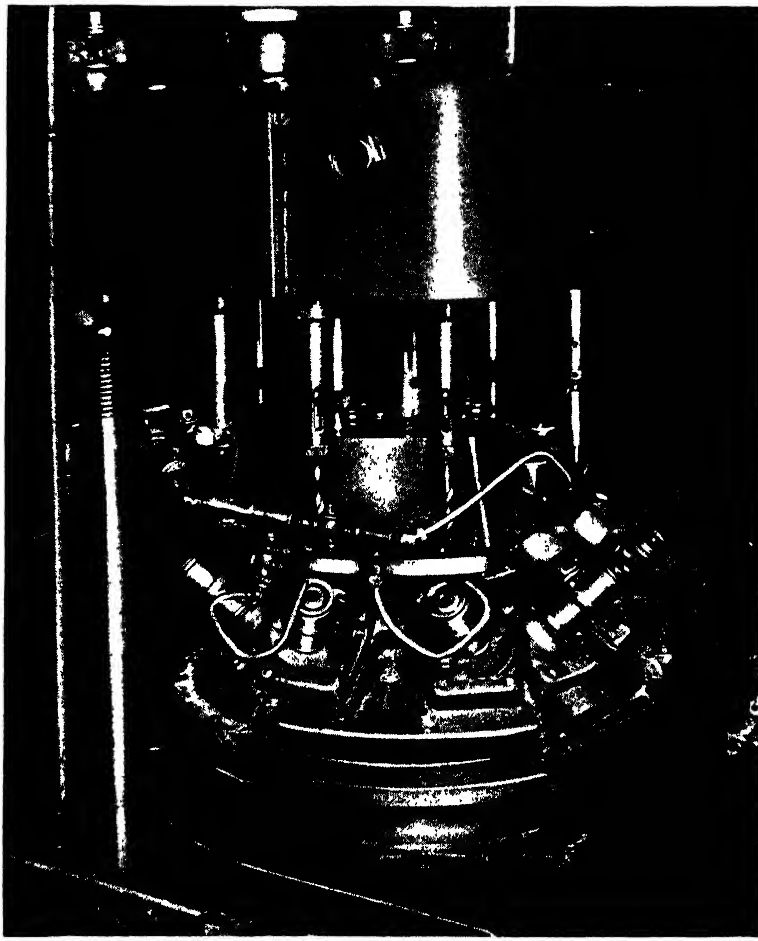

Fig. 3. Special Machine for Drilling, Counterboring, Spot-facing, and Tapping an Angular Hole in Hydraulic Cylinders for Front Wheels of Automobiles

tapping the holes surrounding the half-bores. The holes tapped are 7/16 inch in diameter and have fourteen threads per inch.

Drilling, Counterboring, Facing and Tapping.—Drilling is often followed by tapping in the same machine. Standard drilling machines frequently are used for tapping. The example of work to follow illustrates the application of a special machine.

Right- and left-hand hydraulic cylinders for front wheels of cars are successively drilled and counterbored, drilled a second time, spot-faced, and tapped in four stations of the five-station indexing type of machine shown in Fig. 3. The fifth station is used for reloading. With each indexing of the work-table, the hydraulically actuated fixture makes a feeding movement upward and a quick return. A right- and a left-hand cylinder are held in each station of the work fixture in the necessary positions for machining the hole at the prescribed angle in each cylinder. The machine head is provided with eight spindles, so that one piece of each hand is completed with every indexing of the fixture.

Machine with Reversing Motor for Withdrawing Tap.—Cylinders for the rear wheels of cars are drilled and tapped by the machine illustrated in Fig. 4. This machine is equipped with a hydraulic head for performing two drilling and countersinking operations, and with a tapping head that has a lead-screw for positively feeding the taps. A reversing motor on this head provides for withdrawing the taps upon the completion of the operation.

The work fixture indexes counter-clockwise beneath the two heads, a right- and a left-hand wheel cylinder being held in each station of this fixture also, so that one part of each kind is completed with each indexing. Two stations at the front of the fixture are always idle for reloading.

Tapping 156 Holes Simultaneously.—The operation illustrated in Fig. 5 consists of tapping 156 holes simultaneously in cylinder heads and crankcases. This operation is performed by a machine which is equipped with three

multiple-spindle heads. These heads are operated vertically to and from the work by hydraulic power. Fifty-four taps are provided on the left-hand head, which taps the crankcases; thirty-four on the central head, which taps the coolant jacket side of the cylinder heads; and sixty-eight on the right-hand head, which taps the camshaft side of the cylinder heads. The cylinder heads and crankcases are

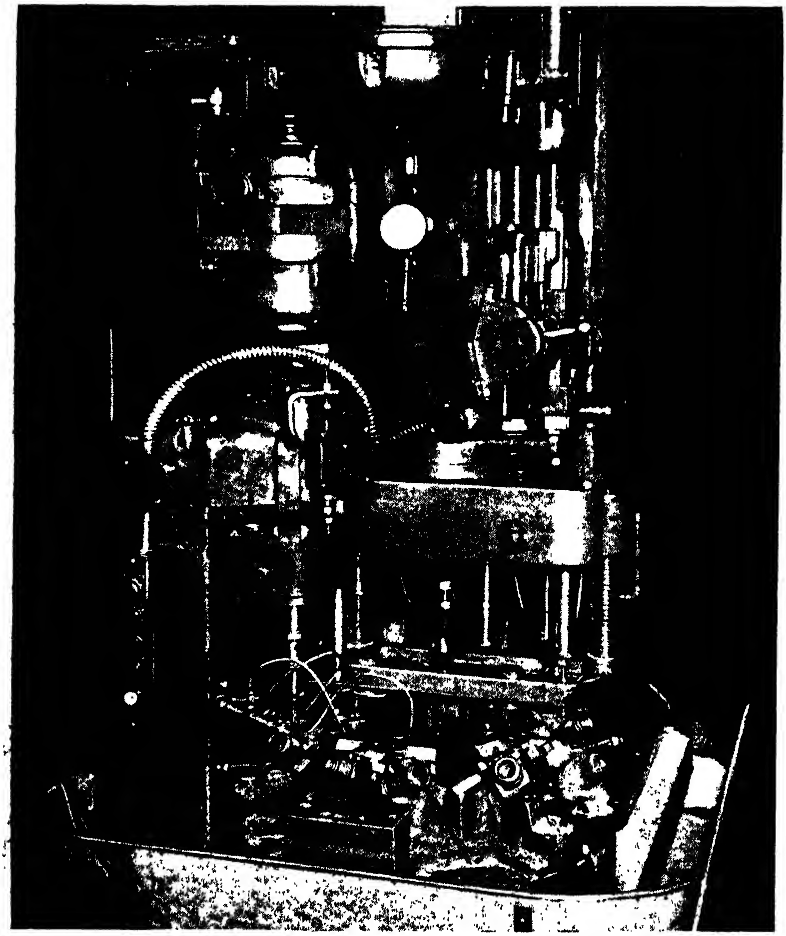

Fig. 4. Another Special Machine Designed for Drilling, Countersinking, and Tapping a Hole at an Angle in the Hydraulic Cylinders for Rear Wheels

held securely in the fixtures by clamps that are also actuated by hydraulic means. The taps range from 5/16 to 5/8 inch in diameter.

Horizontal Type of Multiple-spindle Machine.—The multiple-spindle semi-automatic machine shown in Fig. 6 is used for drilling, counterboring, and tapping sixteen counterweight screw-holes in tractor crankshafts. This machine is equipped with three multiple-spindle hydraulically operated heads and one tapping head actuated by a lead-screw. Six cycles of the machine are required to complete the operation on one crankshaft, the machine table being indexed crosswise between each cycle in order to bring the four cranks successively into line with all the heads.

In the first indexed position of the table and fixture, four

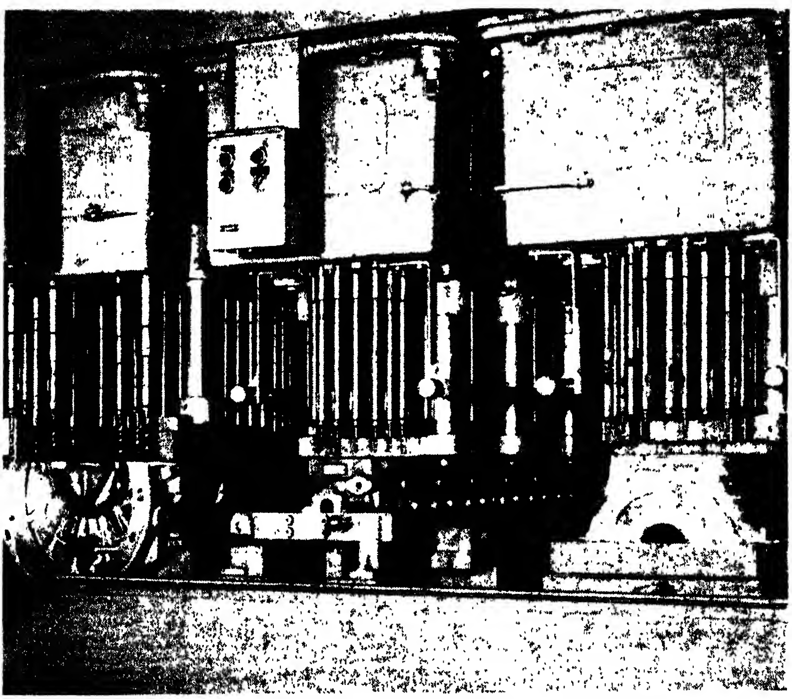

Fig. 5. Tapping 156 Holes in Crankcases and Cylinder Heads in a Hydraulically Operated Machine

holes are drilled in the No. 1 crank by means of the multiple-spindle head at the front right of the machine. The work is then turned through 180 degrees on its fixture, and the table is indexed through one space to bring the work into the second position, where four holes are drilled in the No. 2 crank by the front right head, and at the same time the holes previously drilled in the No. 1 crank are counterbored by the tools on the front left head.

After the fixture has been indexed into the third position, four holes are drilled in the No. 3 crank with the front right head. The four holes in the No. 2 crank are counterbored with the rear right head and the four holes in the No. 1 crank are tapped with the rear left head. The crankshaft is then again revolved through 180 degrees and

Fig. 6. Machine Used for Drilling, Counterboring, and Tapping Sixteen Counterweight Screw-holes in Crankshafts for Tractor Engines

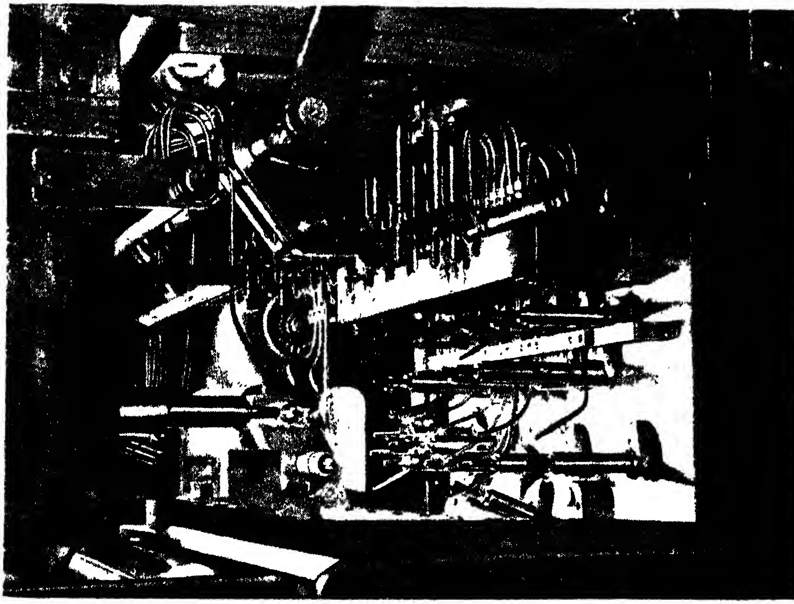

Fig. 7. Special Machine Designed for Tapping Holes in Cylinder Blocks

Fig. 8. Machine Designed for Drilling, Chamfering, and Tapping Four Holes in Crankshaft Flanges

the fixture indexed into the fourth position. Here four holes are drilled in the No. 4 crank with the front right head, the four holes in the No. 3 crank are counterbored with the front left head and the four holes in the No. 2 crank are tapped with the rear left head.

The fixture is then indexed to the fifth position for counterboring the four holes in the No. 4 crank with the rear right head and tapping the four holes in the No. 3 crank with the rear left head. Again the crankshaft is indexed through 180 degrees and the fixture indexed to bring it into the sixth position for tapping the four holes in the No. 4 crank with the rear left head. Eight or nine crankshafts are produced per hour.

Tapping Cylinder Blocks.— In automotive plants where the production is large, machine tools are often designed expressly for a given job. The tapping machine illustrated in Fig. 7 is an example. This machine is employed for tapping the many holes in the cylinder blocks. As will be seen from the illustration, it is designed for feeding taps from the top, the two sides and one end, both straight in and at an angle.

Indexing Type of Drilling and Tapping Machines.—The four holes in crankshaft flanges are drilled, chamfered, and tapped in three stations of the indexing type multiple-spindle machine shown in Fig. 8. Drilling occurs in the first station at the front, chamfering in the bottom station and tapping in the rear station. The work drum is locked in the various settings by a plunger that enters bushings provided in arms of the fixture. The crankshafts are reloaded in the uppermost fixture position.

Drilling Holes with Machines of Single-Spindle Type

In the application of drilling machines, there are a number of different conditions which affect the selection of a suitable type of machine. Factors which frequently are important may be summarized as follows:

1. Number of holes to be drilled in a given time and variations, if any, as to sizes.
2. Operations, if any, which may follow drilling, such as reaming, counterboring, or countersinking. (Successive operations may be performed by inserting different tools in a quick-change type of chuck, or a multiple-spindle machine may be used so that each tool remains in its spindle and the work is moved through successive working positions.)
3. Location and spacing of the holes, especially as these factors may relate to the drilling of all holes successively or simultaneously.
4. Size or weight of work, particularly when either drill spindle or work must be shifted for drilling in different locations.

The examples in this and a following section show how different types of machines are adapted to various classes of work, especially when there is some unusual or interesting feature connected with the drilling operation.

Precision Depth Drilling Operation.—In Fig. 1 is shown a sensitive drilling machine equipped with a tool fixture of unique design for drilling a hole 0.150 inch in diameter almost the full length of the striker pins of percussion fuses, from the end opposite the needle point. The bottom of the hole must be the specified distance from the needle

point within 0.005 inch—an exacting requirement, in view of the fact that the hole must be measured from the opposite end of the piece. The hole is approximately 1 inch deep.

The operation of this machine differs from the usual practice in that the work pieces are inserted one at a time

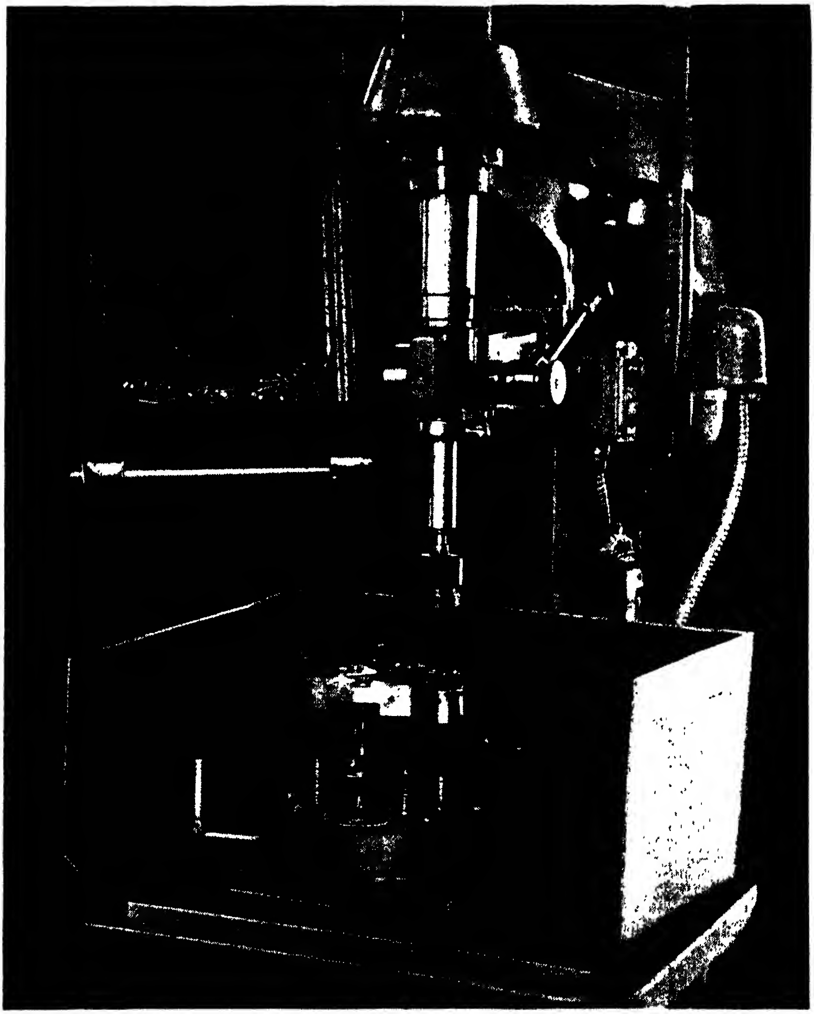

Fig. 1. Ingenious Fixture Provided on a Sensitive Drilling Machine for "Gun Drilling" a Small-diameter Hole in Striker Pins

in a chuck held on the machine spindle. The three-position fixture on the machine table is provided with three stationary drills that are held vertically in line with guide bushings in overhead bars. The bushing bars are supported on springs, which are pushed down when the nose of the chuck comes in contact with the bushing to feed the work through the bushing and down over the drill. The rotating chuck is made with a small tapered nose that engages a conical seat on the guide bushings and causes them to revolve with the work.

With the first station of this fixture beneath the machine spindle, the small-diameter hole is drilled to one-half its depth in the striker pin. The hole is then drilled to its full depth in the second station of the fixture. In the third station, the upper end of the hole is counterbored.

Machine Equipped with Combination Hole-locator and Drill Guide.—The operation illustrated in Fig. 2 consists in drilling sheets according to steel templets or jigs that are only 0.005 inch in thickness. Locating holes in these templets are made 5/16 inch in diameter to receive a "finder" attached to the lower end of the drill spindle. This finder serves both as a means of accurately locating the drill for each drilling step and as a bushing to guide the drill accurately through the stack of sheets. One of these finders is seen lying upside down near the front end of the stack of sheets in the left foreground of the illustration. There is a locating nose on the finders which is of approximately the same length as the thickness of the templet and is of the same diameter as the templet holes. The finder shank is provided with a groove which is engaged by a ball lock for attaching it to the drill spindle.

As many as 500 holes are frequently drilled through the stack of sheets in the manner described, some of them for locating purposes in routing and subsequent operations, and others for receiving rivets in assembling operations. The drill heads are also driven by high-cycle electric motors at speeds ranging from 1700 to 5600 R.P.M. Timken tapered roller bearings in the radial arms provide a finger-tip movement of the drill head over the sheets.

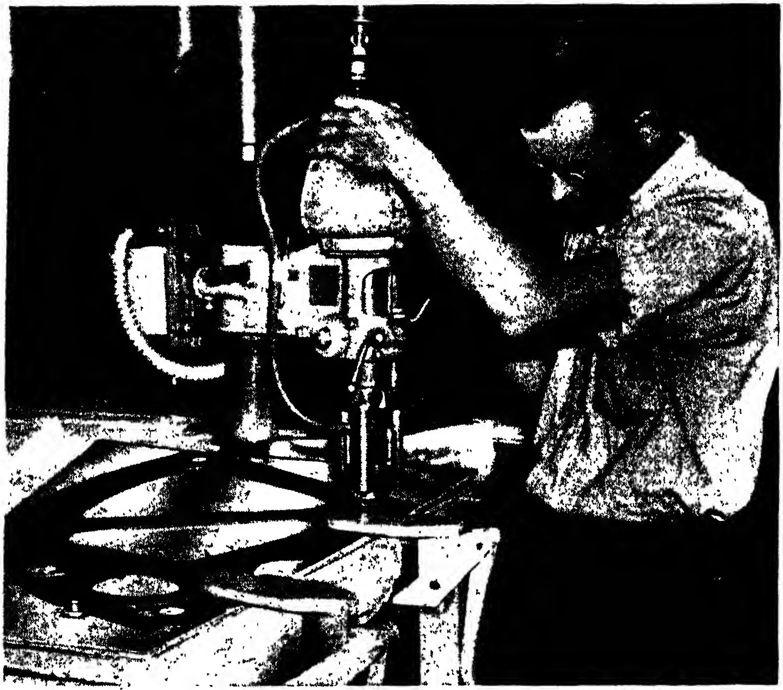

Fig. 2. Locating and Rivet Holes are Accurately Drilled through Stacks of Sheets by Using Templets and a "Finder"

Automatic Drilling Equipment with Pneumatic Feed Mechanism.— Automatic drilling units are saving many hours in drilling the thousands of rivet holes required in aluminum alloy sheets for airplanes. With these units, the operator merely pushes an electric button to start the automatic feeding of the drill after it has been located correctly on the work. A close-up view of one of these automatic drilling units is shown in Fig. 3. When the operator pushes the button, a solenoid switch is operated to cause air to be admitted into a pneumatic cylinder for quickly feeding the drill head down to the work.

Drilling is accomplished in two strokes of the drill spindle, the drill being withdrawn from the hole when it is half way through, to permit it to free itself of chips. At

the end of the second drilling step, the air cylinder quickly "snaps back" the drill spindle to the starting position. With this speedy equipment, an operator drills as many as 190,000 holes in an eight-hour day, whereas with a hand-fed unit, a production of 4500 holes was considered a good day's work.

The sheets to be drilled are stacked to a thickness of about 7/16 inch on the table. With the thinner sheets, this means twelve to fifteen sheets, and with the thicker material five to seven sheets. A templet is clamped on top of the stacked sheets, and a conical finder attached to the lower end of the drilling unit is quickly positioned in the templet holes to locate the drill unit for each step of the

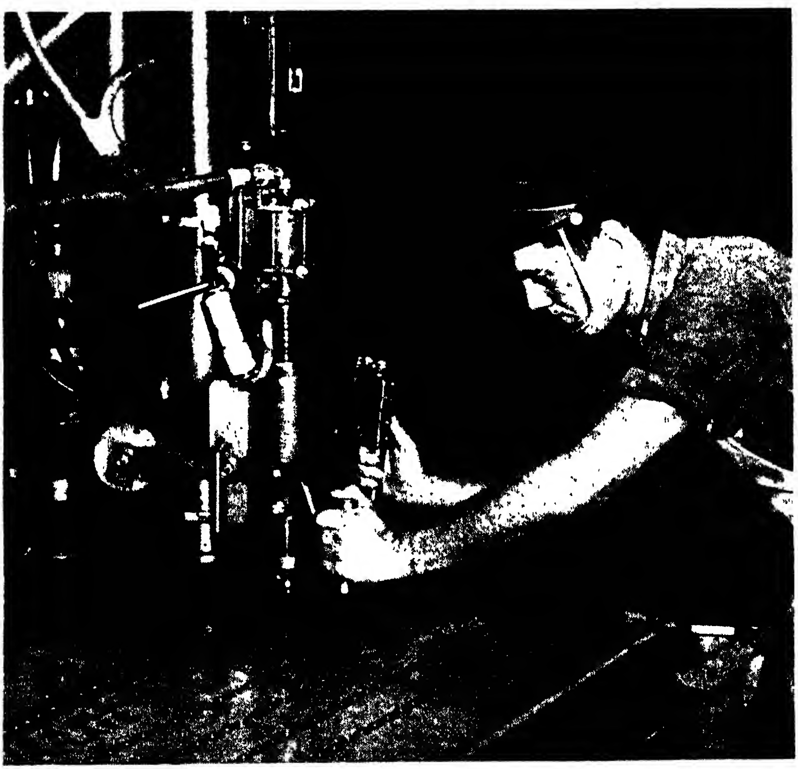

Fig. 3. Drilling Thousands of Holes in Aluminum Alloy Sheets by the Use of This Automatic Drilling Unit

operation. The drill spindle is driven at 14,800 R.P.M. by a 5-H.P. high-frequency motor.

Radial Drilling Machines Equipped with Indexing Types of Drill Jigs.—The radial type of machine has a vertical spindle, which is carried by an arm that may be swiveled about a vertical column. The radial adjustment of the arm about the column, in conjunction with the traversing mo-

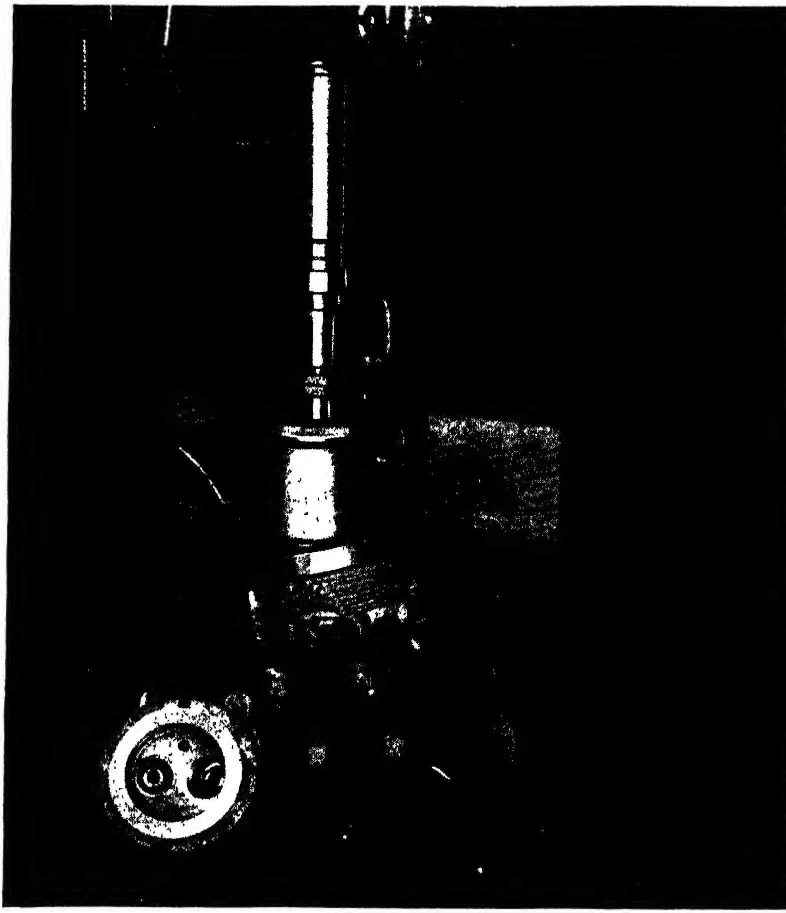

Fig. 4. Indexing Type of Jig Employed in Connection with a Radial Drilling Machine for Machining the Valve-guide and Valve-stem Holes in Airplane Engine Cylinder Heads

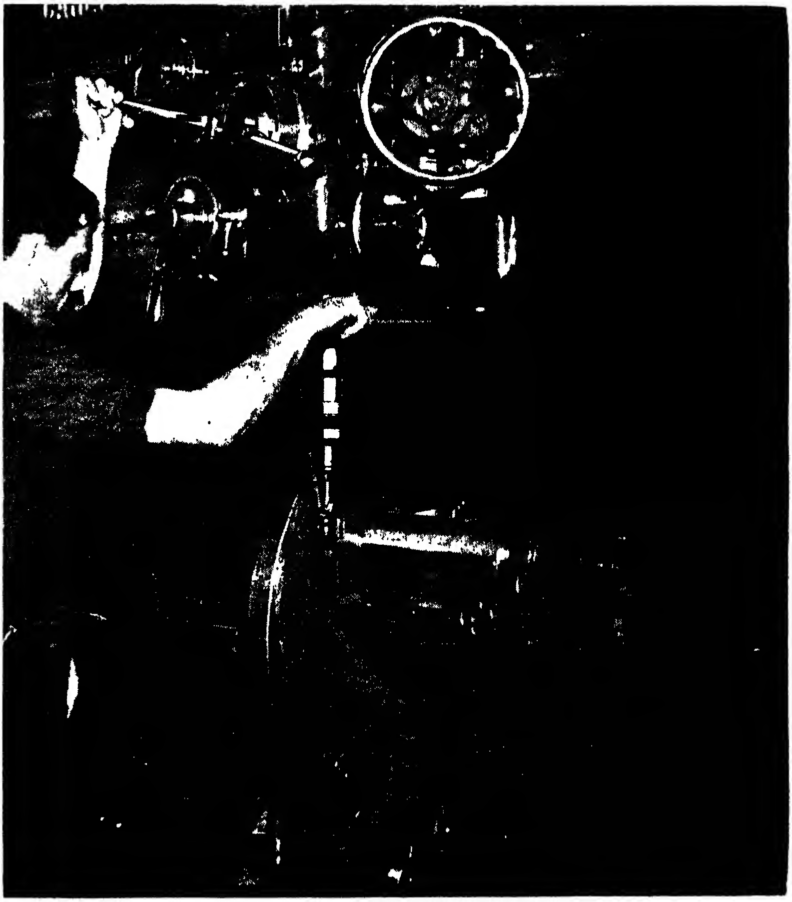

Fig. 5. Drilling Main Strut of Airplane Landing Gear

tion of the drill-spindle head along the arm, makes it possible to readily locate the drill in any position within the range of the machine, which is a decided advantage when drilling heavy parts that could not be shifted easily.

The application of a radial drill for drilling, boring, and reaming valve-guide and valve-stem holes in airplane engine cylinder heads is shown in Fig. 4. The work is placed in a jig that is free to slide on the vertical face of a base member, so that the work can be indexed into two positions to

bring the intake and exhaust chambers of the cylinder head successively into line with the vertical drill spindle of the machine. In indexing, the operator moves a lever to withdraw a locking pin from a dowel-hole in the vertical face of the base, and the jig is then slid around a curved track on the vertical face. There are, of course, two dowel-holes to insure accurate holding of the jig in both indexed positions.

The work is located in the jig from its upper flange surface, which is seated in a hardened and ground ring and clamped there by the operation of a lever underneath the

Fig. 6. Hydraulic Type of Radial Drilling Machine being used for Drilling Holes in an Inspection Plate

work. This lever turns an eccentric shaft which lifts a two-arm bracket against the bottom of the cylinder head. A large bushing is provided at the top of the jig to guide all tools employed in this operation, there being a corresponding pilot sleeve on the drill spindle in back of the tools.

Another indexing type of jig is shown in Fig. 5. Seven holes are drilled in the main struts of airplane landing gears, by using the radial drilling machine shown with the work held in a jig that can be indexed through 90 degrees. The jig is locked in its two settings by manipulating a handle on the base, which causes plugs to enter holes in indexing members at the opposite ends of the jig. The small end of the strut is held in a V-block at the left-hand end, while the large end is seated on a block, mounted on a slide which can be moved back and forth on ways of the jig.

Hydraulic Operation of Radial Drilling Machine.—The hydraulic features of the radial drilling machine shown in Fig. 6 are proving advantageous in performing the varied operations that come up in the machine shop of a shipyard. In the illustration, this machine is being used for drilling 1 1/4-inch diameter holes through an inspection plate. Thirty-six spindle speeds are obtainable through a hydraulic gear-shifting mechanism; the head can be traversed hydraulically along the arm at variable rates; the arm is raised and lowered hydraulically; and the outer column is clamped to the inner column by hydraulic means. The machine is provided with a 5-foot arm, and has a column 15 inches in diameter.

Drilling Armor Grating for Naval Vessels.—The drilling operation on armor grating shown in Fig. 7 consists of drilling large numbers of holes, 5 inches in diameter, through the grating. From fifty to several hundred holes are drilled in one piece of grating, the number depending upon the over-all dimensions of the grating.

This operation is performed by employing a radial drilling machine. First, the end holes to be drilled in each row are laid out. Then these holes are drilled, after which

templets, such as seen at the right-hand end of the grating in the illustration, are employed for locating the remaining holes, the templets being fastened to the drilled end holes.

In producing these holes, a 2-inch diameter drill is used first, this drill being run at a speed of 88 R.P.M., with a feed of 0.014 inch per revolution. After all the holes in one group have been drilled to this size, a head with a fly cutter is substituted for the drill, and a bushing of suitable size is slipped into the templet opening. The holes in the grating are then enlarged to a diameter of 3 1 4 inches, the fly cutter being driven at a speed of 34 R.P.M. and fed

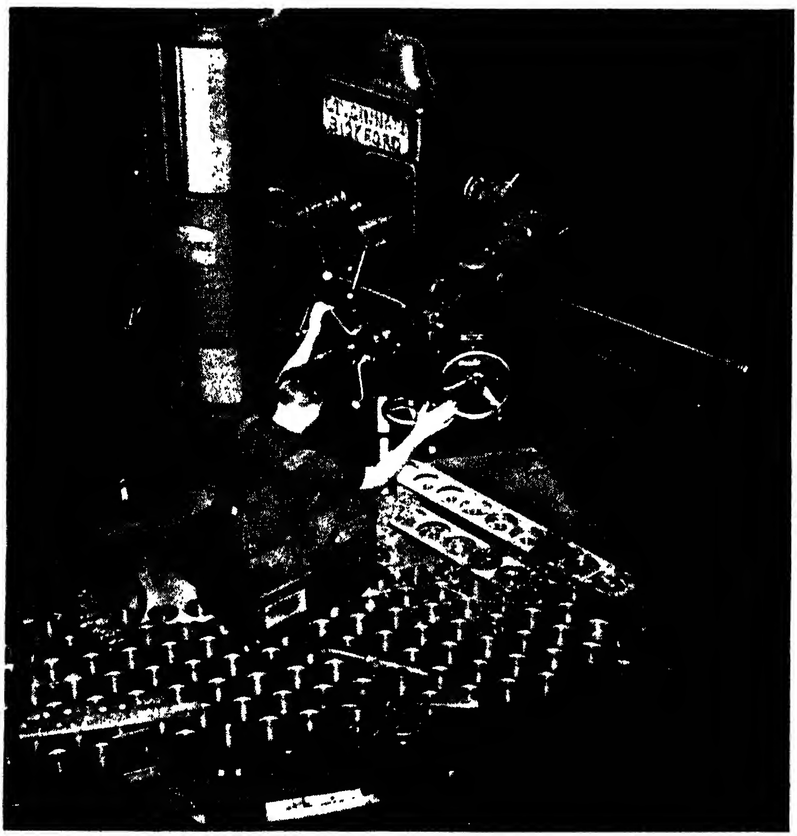

Fig. 7. Drilling 5-inch Holes through Armor Grating on a Radial Drilling Machine

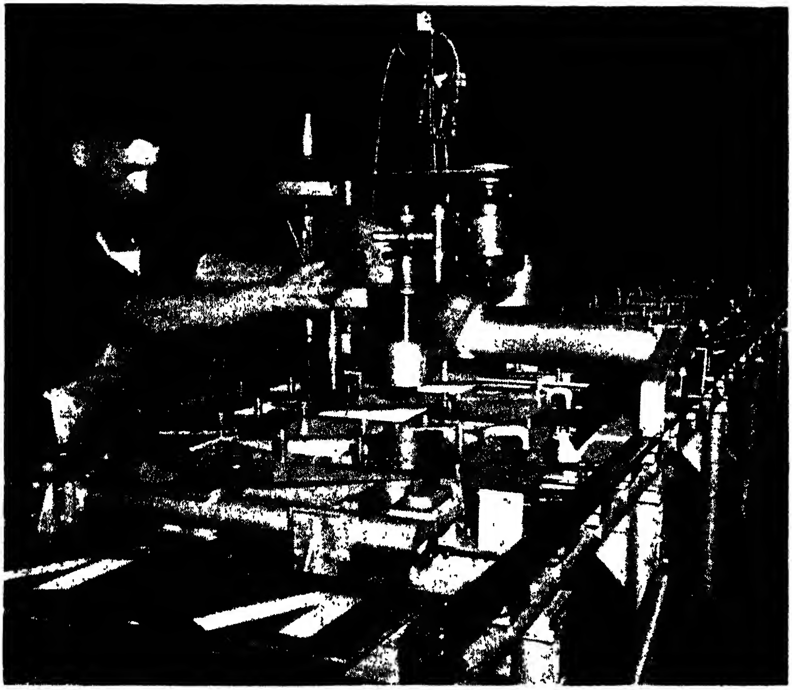

Fig. 8. Drilling with Traveling Drill Head Mounted on Jig Tracks

downward at the rate of 0.017 inch per revolution. When all the holes in one group have been bored to the size mentioned, an OK cutter-head fitted with inserted blades of high-speed steel is substituted for the fly cutter, and other bushings are provided in the templet openings. With this cutter, the holes are enlarged to a diameter of 5 inches. This cutter is run at a speed of 24 R.P.M., and is also fed at the rate of 0.017 inch per revolution.

Frequent grinding of the drills and cutters is necessary on account of the extreme hardness of the armor plate near the top and bottom surfaces and the toughness of the metal between these surfaces. The thickness of the grating varies with different types of vessels. In building one cruiser, it was necessary to drill a total of 8954 holes through grating that was 6 1/2 inches thick.

Traveling Drill-head Type of Machine.—Drilling of the multitudinous rivet holes required in aircraft building is facilitated at one plant by the use of traveling drill heads which can be moved back and forth over long work. In Fig. 8 typical equipment of this type is seen arranged to run along tracks mounted on the sides of a wing-spar jig. The drill head is pivoted on its carriage, so that it can be swung around an arc for drilling holes located any-

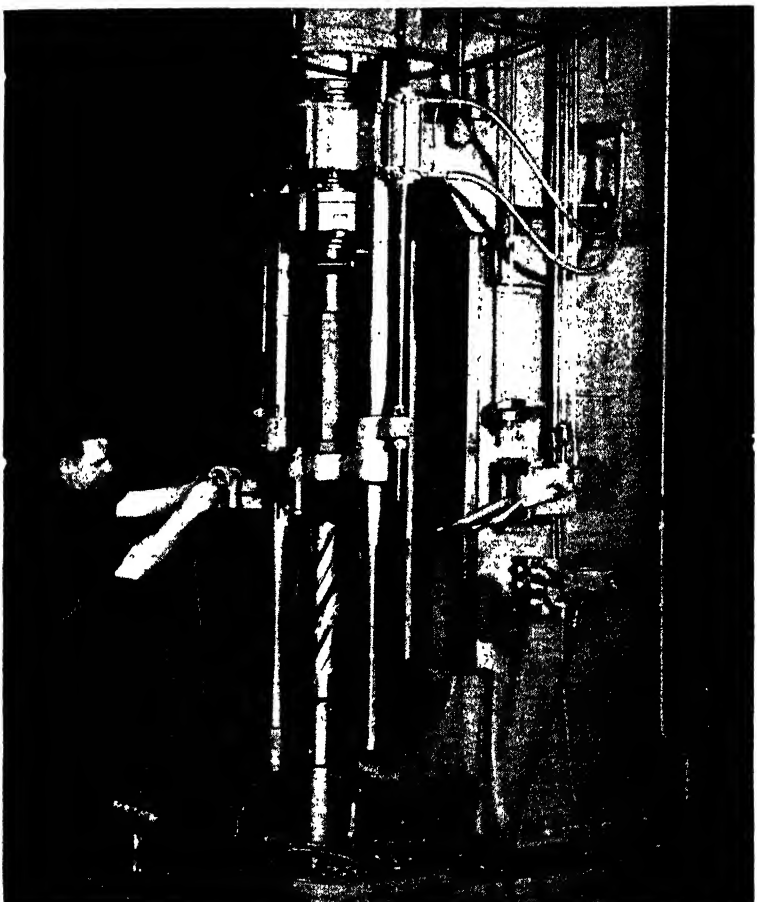

Fig. 9. Drilling Machine of Inverted Type, with Rotating Work above the Stationary Drill

where on jig templets fastened above the work. The drill carriage has a span of approximately 4 feet, the length of the jig tracks being about 50 feet.

An interesting feature of these drilling operations is that the various templet holes are surrounded by circles painted in different colors in accordance with the sizes of the holes to be drilled through them. Circles of blue, red, and white, for example, denote three different sizes of holes, and the operator knows at a glance what the sizes are.

Larger airplane sections are similarly drilled by the use of a gantry drill which is arranged to run on a track 24 feet wide by 100 feet long. The drill head can be moved sidewise on its carriage, which has a width of about 6 feet, and the carriage can be moved back and forth the full width of the gantry structure. The latter can, of course, be operated the full length of the 100-foot track. Jigs located on the floor between the track rails are served by this equipment, it being the practice to prepare work in several jigs while work is being drilled in jigs previously loaded. Large bulkheads and center-section spans are typical assemblies drilled with this equipment.

Drilling Large Hole on Machine of Inverted Type.—A large drilling machine designed to operate in a manner that is exactly the reverse of conventional practice, in that the work is above the drill and revolves while the drill remains stationary, is shown in Fig. 9. This machine is equipped for drilling a hole 4 1/4 inches in diameter through solid bars of steel 16 1/2 inches long, which are to be made into airplane engine propeller shafts. The upper end of the work is held in a chuck and the lower end in a special steadyrest, adjustable vertically along guide bars. The work-head is rapidly traversed by hydraulic power to the drill and then fed hydraulically at a slower speed for the drilling, which requires twenty minutes.

With this drilling method, no difficulty is experienced from chips clogging the drill, because they tend to fall away from the drill point. In addition, coolant at a pressure of 300 pounds per square inch is fed to the drill point through

tubes embedded in the drill lands, which insures the discharge of all chips. Accurate centering of the hole throughout the full length of the propeller shaft is also facilitated by this unusual method of drilling. Previous to the application of this method, the practice was to first drill a small hole through the shaft and then enlarge it to the required diameter in a succession of drilling operations.

Drilling Holes with Machines of Multiple-Spindle Type

Multiple-spindle machines are used extensively either to facilitate successive operations or for drilling a number of holes simultaneously. Some machines designed for drilling holes simultaneously are so arranged that the positions of the spindles may be adjusted to suit different hole locations, thus adapting the machine to the drilling of different parts provided the hole layouts are within the minimum and maximum range of adjustment. Other types of multiple-spindle machines are designed with fixed spindles arranged for drilling duplicate parts only. Such machines are often used in the automotive industry where large numbers of duplicate cylinder blocks, crankcases, etc., are required.

The multiple-spindle type is built in both vertical and horizontal designs. Some drilling machines equipped with multiple spindles are known as *gang drills*. The term "gang drill" is generally applied to a vertical design practically consisting of several machines combined in one unit, and with the spindles all in the same vertical plane. Machines of this general design are also referred to as multiple-spindle drills, by many manufacturers. Drilling machines, however, having spindles which are arranged in a group so that they may be adjusted according to the respective positions of the holes, whether in a straight line, on a circle, or irregular as to location, are especially known as multiple-spindle types. This is also true of the type having a fixed cluster or group of spindles arranged for a specific job.

Some drilling machines having more than one spindle are named according to the number of spindles, as, for example, a four-spindle sensitive drilling machine, etc. In other

cases, a special design of machine having several spindles is classified according to the work for which it is intended.

Four-spindle Machine Having Pneumatic Type of Feed Mechanism.—The feed mechanisms of drilling machines usually are the geared type. The four-spindle machine illustrated in Fig. 1 utilizes air pressure for operating the drill spindles and work-holding chucks. It drills cast-iron valve-stem guides for automobile engines. These guides are 2 inches long and are drilled the full length to a diameter of 19/64 inch. For this operation, each guide is held between the conical seats of two chucks, the bottom chuck being raised and lowered by means of an air cylinder for reloading purposes. When the bottom chuck is raised, air is admitted into the cylinder of the drill-spindle unit to

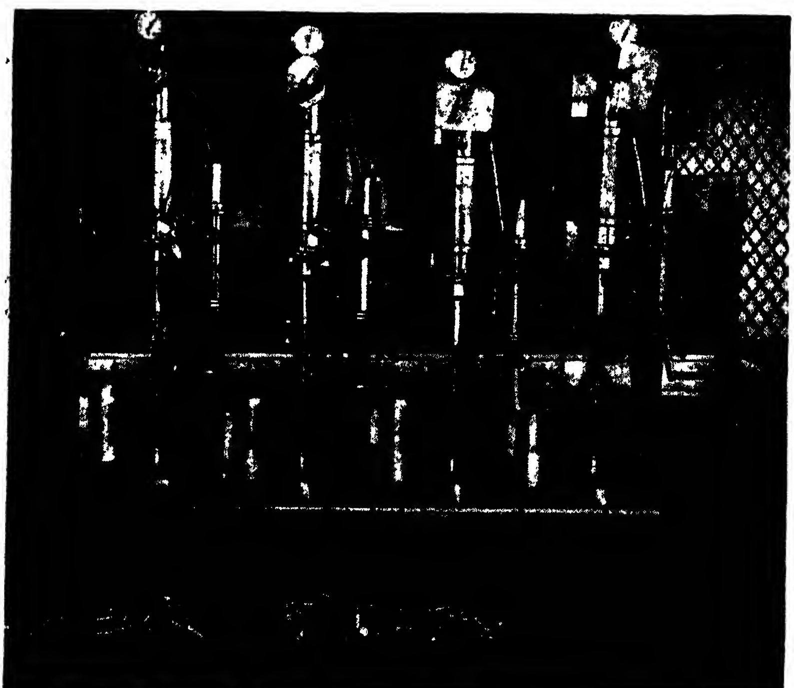

Fig. 1. Four-spindle Machine Employed for Drilling 5000 Valve-stem Guides per Eight-hour Day

start feeding of the drill. Air for operating both the bottom chuck and the drill spindle is controlled through one lever, which is seen at the right of each spindle. One man loads the four stations of this machine, and drills, on the average, 5000 pieces per eight-hour day. The air pressure applied to feed each spindle is regulated according to a gage at the top of the spindle air cylinder.

Spot-facing and Drilling Thirty-two Bolt Lugs on Multiple-spindle Machine.—The machine shown in Fig. 2 is used for spot-facing thirty-two bolt lugs at one time on rocker-arm covers. The same machine is also employed for spot-facing corresponding lugs on cylinder heads, in which case the work-piece is mounted on the other side of the fixture. The fixture is indexed through 180 degrees to bring this side of the fixture uppermost when cylinder heads are being

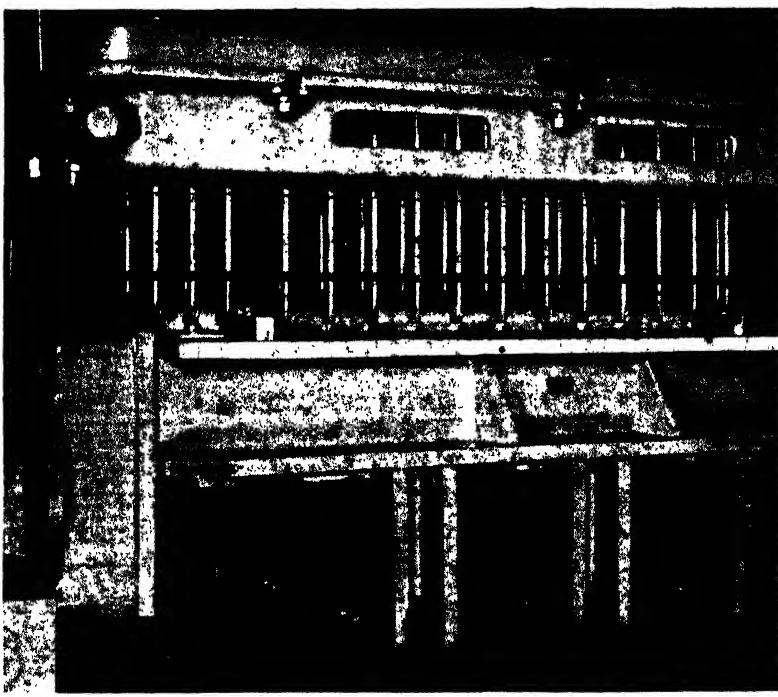

Fig. 2. Spot-facing and Drilling Rocker-arm Covers and Cylinder Heads on Machine Equipped with an Indexing Fixture

handled. Indexing is accomplished by turning a large handwheel, there being a locking arrangement to hold the fixture in the indexed positions.

The same machine is also used for drilling holes through the bolt lugs of both cylinder heads and rocker-arm covers, in which case the fixture is indexed so as to place the cast-

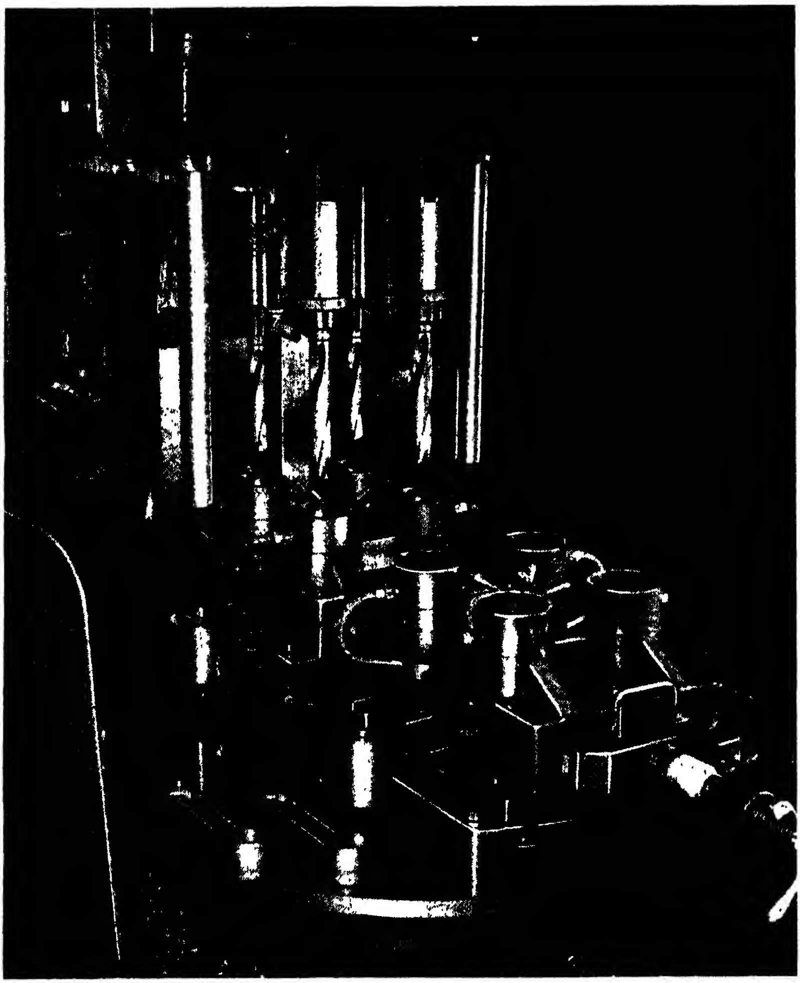

Fig. 3. Four-spindle Machine Equipped with Duplex Type of Work-holding Fixture

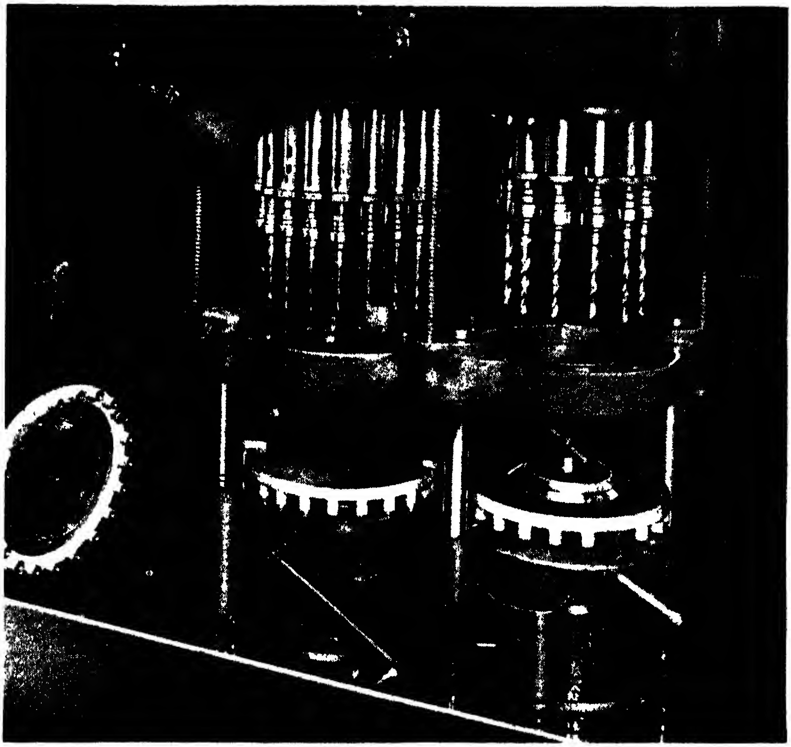

Fig. 4. Vertical Drilling Machine Having Two Multiple-spindle Heads for Drilling the Trunnions of Reduction-gear Carrier-rings and a Flange Inside the Trunnions

ing on the under side. The drills can then be guided through bushings in the fixture. However, the castings are always loaded with the side of the fixture to which they are to be fastened uppermost.

Four-spindle Machine Having Duplex Work-holding Fixture.—Fig. 3 shows a four-spindle machine equipped for simultaneously drilling the piston- and knuckle-pin holes in two airplane engine articulated connecting-rods. The holes in the bosses are of different sizes, one being 1 21/64 inches in diameter, and the other 1 31/64 inches. Duplicate sets of fixtures are provided so that parts can be loaded in one set while parts in the other set are being

machined. Accurate location of the fixtures beneath the drill head is insured by the use of two long pilot bars on the multiple-spindle head which enter corresponding bushings on the fixtures. Each fixture is clamped and unclamped by a socket wrench at the front of the table.

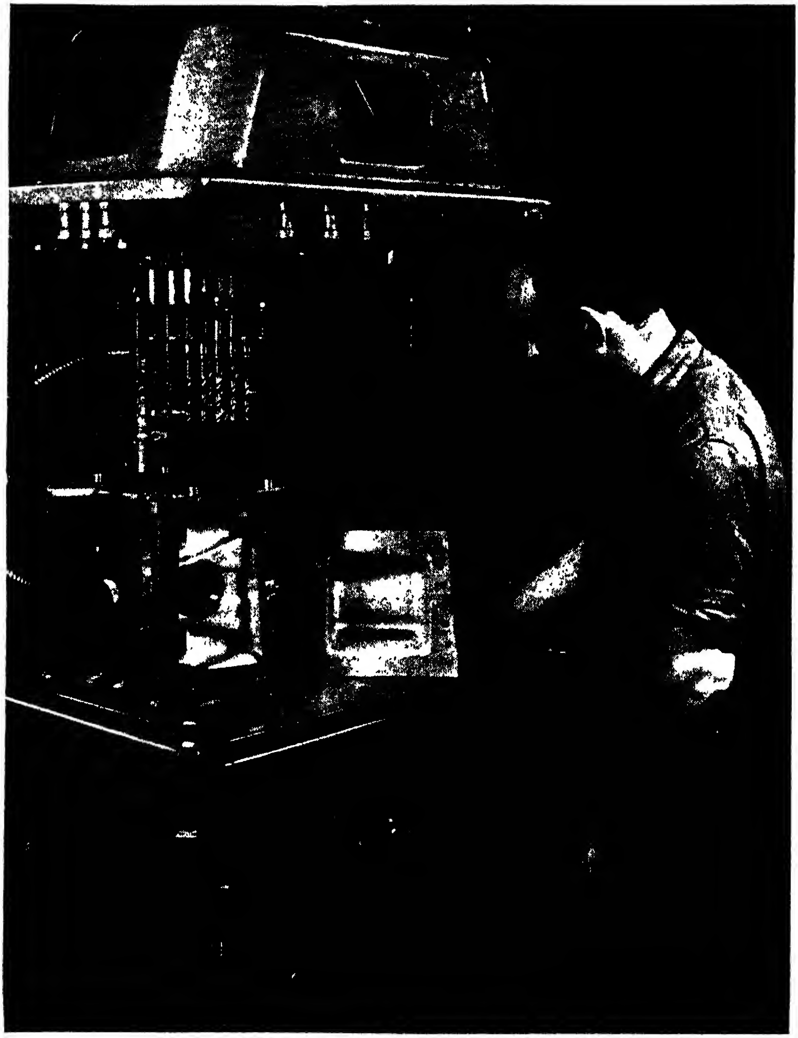

Fig. 5. Multiple-spindle Machine Equipped with Table Operated both by Compressed Air and Hydraulically

Duplex Type of Multiple-spindle Machine for Drilling Two Sets of Holes.— A vertical type of machine, equipped with two multiple-spindle heads for drilling reduction-gear carrier-rings of airplane engines, is illustrated in Fig. 4. The head at the left drills twenty holes, 9/32 inch in diameter through the trunnions from the back of the part. The head at the right is then employed to drill twelve holes, somewhat larger in diameter, through a flange on the inside of the piece. In operation, the jig plate is lowered automatically into contact with the work before the drilling commences. The movements of the jig plate and the tool-heads are derived from a hydraulic system.

Hydro-pneumatic Table Operating Mechanism for Multiple Drilling.— Fig. 5 shows a multiple drilling operation on a machine equipped with a table that is raised almost instantly into the drilling position by compressed air and then fed upward slowly for the drilling operation by means of a hydraulic system. The operation consists of drilling twelve holes on each side of an aluminum forging, the group of drills at the left being used on one side, and the cluster of drills at the right on the opposite side. An adjacent machine of the same type drills nine holes in the bottom of the forging while it is clamped in the same jig. In each operation, an automatic cycle of the machine is started by depressing a foot-pedal.

Drilling, Redrilling and Reaming on Twenty-one-spindle Machine.—In Fig. 6 is shown a twenty-one-spindle machine designed for drilling, redrilling, and reaming seven holes in the legs of aluminum crankcase sections of airplane engines, in one operation. On front and rear crankcase sections there are legs on one side only, but on center sections there are legs on both sides in which the holes must be machined. The holes are drilled to a diameter of 1/2 inch and are 2 1/4 inches deep.

The machine on which this operation is performed is equipped with a jig that is moved from the loading position into the working position and vice versa, by the action of an air cylinder in the center of the sliding jig. When in the

working position, as shown, the jig and the table on which it is slid back and forth can be indexed into three positions in a horizontal plane to enable two drills of different diameters and a reamer to be applied to each leg of the crankcase section. Indexing is effected between three successive vertical movements of the spindles by manipulating a handle at the extreme right of the machine. The crankhandle seen a little farther to the left, through sprockets

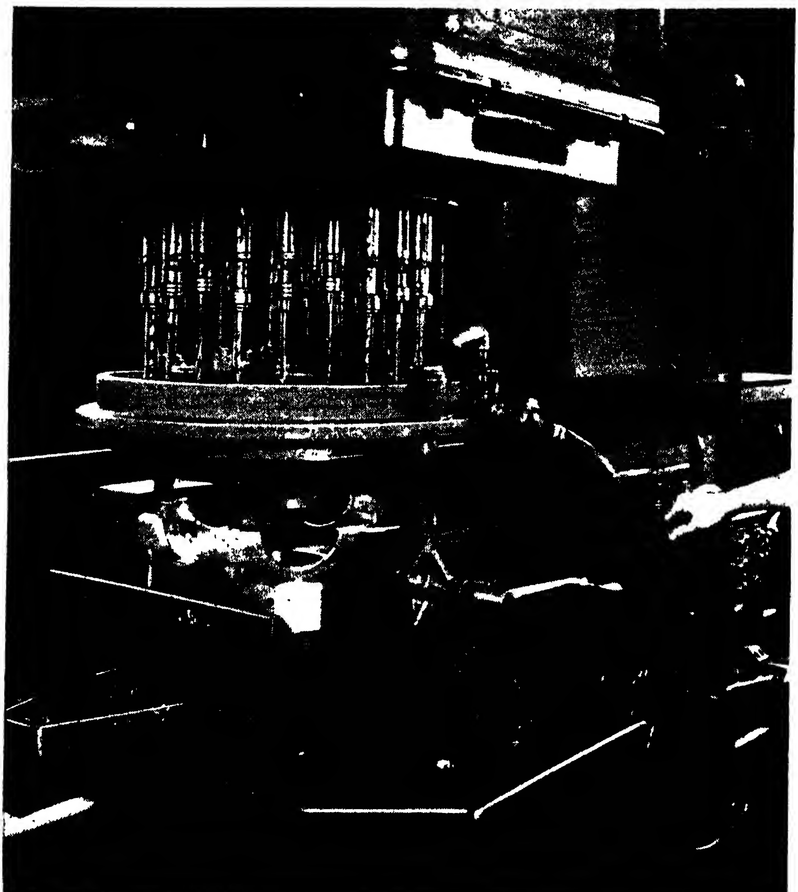

Fig. 6. Twenty-one-spindle Machine Employing Two Drills and One Reamer in Succession for Drilling and Reaming Seven Holes

and a silent chain, lowers the jig bushing plate after each crankcase section has been placed in the working position, and raises the bushing plate when the operation has been completed. The vertical movements of the spindle head are effected by hydraulic power. The time taken in drilling and reaming the holes in the crankcase sections is now only

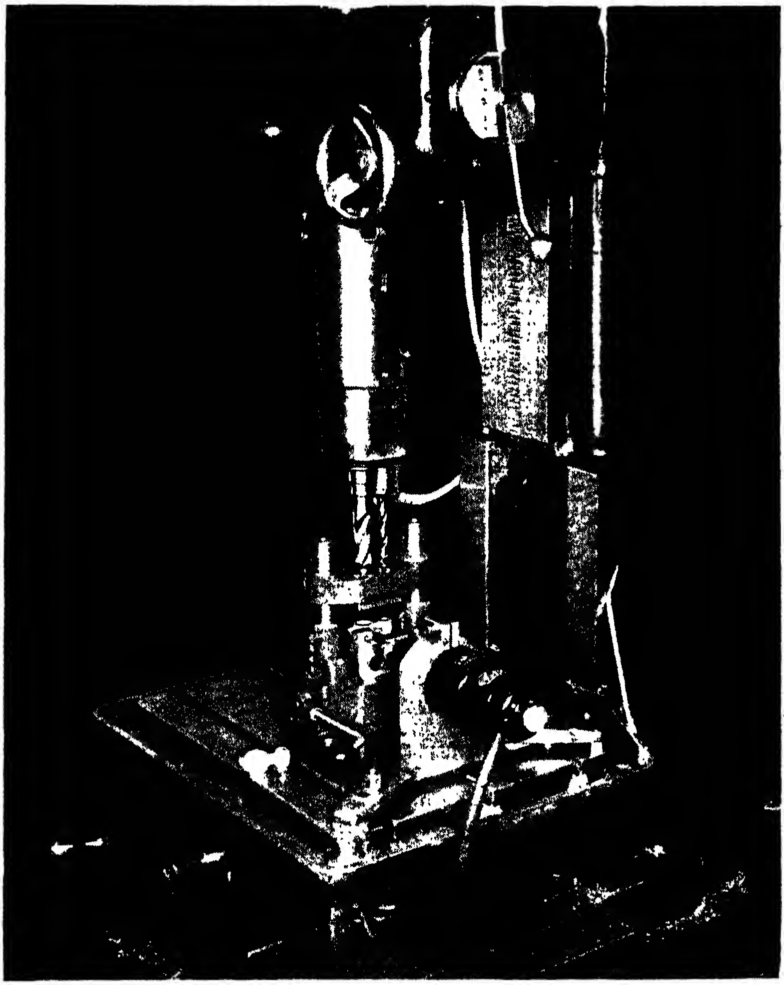

Fig. 7. Drilling Operation in which a Special Two-spindle Head Drills Two Holes Vertically while an Electric Unit Drills Another Hole Horizontally

about one-fifth that required with the method previously used.

Machine Equipped for Drilling Both Vertically and Horizontally.—The machine shown in Fig. 7 utilizes a cam-operated drill jig in conjunction with a special head on the machine spindle that carries two drills and an electrically driven automatic drilling unit, mounted on the same base as the jig. With this set-up, two holes are drilled vertically in the part, and a third hole horizontally, all at the same time. These drilled parts are used on a certain type of airplane. Twenty-eight of the parts are required on each airplane. When a sufficient number of parts have been drilled to meet production schedules for a desired period of time, the automatic drilling unit can be transferred to other fixtures for similar applications.

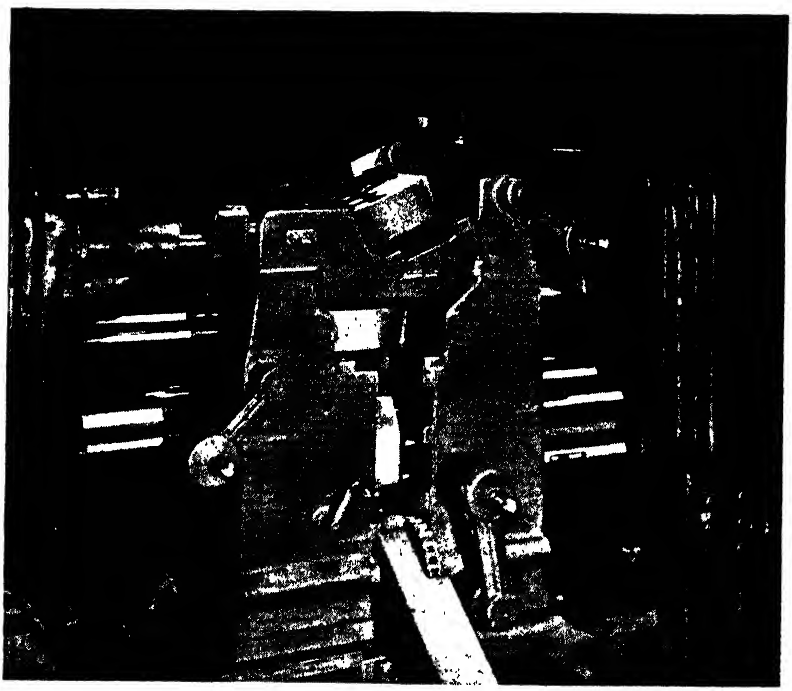

Fig. 8. Four-station Multiple-spindle Drilling Machine which Drills All Holes in Tractor Cylinder Heads with Two Machine Heads

Drilling Tractor Cylinder Heads on Four-station Multiple-spindle Machine.—All holes in tractor cylinder heads, including the angular spark-plug holes, are drilled by the multiple-spindle machine shown in Fig. 8, which is equipped with two hydraulically operated heads that slide on horizontal ways of the bed. Each cylinder head is placed in four stations of the jig. When a cylinder head is in the two bottom stations, the top and bottom sides of the cylinder head are held in vertical planes; in the next station, it is held horizontally; and in the last (at the top), angularly. The cylinder heads are placed in the bottom station by means of dogs on a chain that is operated by a crank-handle. Clamps which are also operated by crank-handles hold the cylinder heads firmly in the various stations.

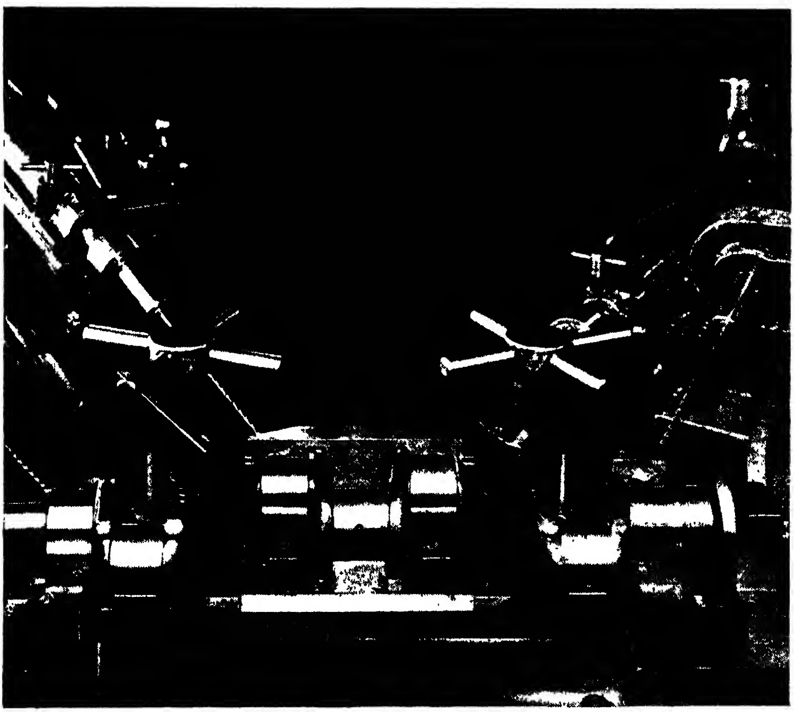

Fig. 9. Six Oil-holes are Drilled Simultaneously in Crankshafts by Independent Hydraulic Heads

Machine Equipped with Six Independent Drilling Units.—Six oil-holes are drilled simultaneously in automobile engine crankshafts on a machine equipped with single-spindle hydraulically operated drilling heads arranged at the front, back, and one end of the machine (Fig. 9). These heads operate on ways located in various angular positions as required for drilling through the bearings and crank-arms. The drill heads are so designed that if the load on a drill becomes excessive, due to a dull tool, too great an accumulation of chips in the hole, or a hard spot in the crankshaft, the head will reciprocate rapidly until the condition is remedied, so that the operator is immediately informed of

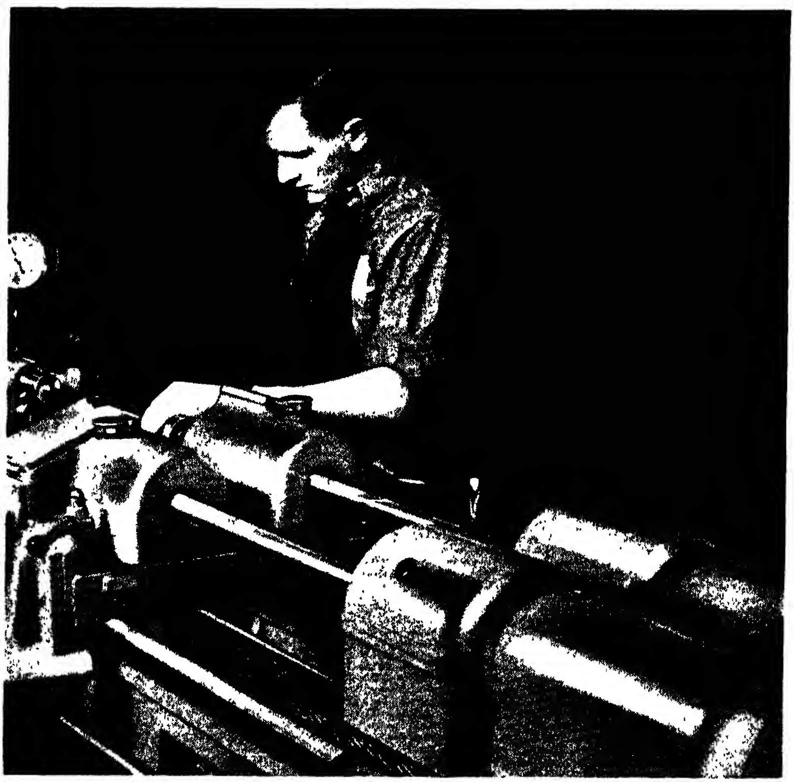

Fig. 10. Two Machine-gun Barrels are Drilled at a Time on a Machine that Feeds Single-flute Drills through the Barrels at 1¼ Inches a Minute

the condition. The drill heads return automatically to the starting position after an operation.

Drilling Machine-gun Barrels. — The drilling of machine-gun barrels is illustrated in Fig. 10. The gun drilling machine shown drills two barrels at one time. Single-flute drills in heads attached to carriages seen at the left are fed through the barrels at the rate of 1 1/4 inches a minute. During the operation, oil at a pressure of between 500 and 600 pounds per square inch is forced through a hole that extends through the center of each drill stem to the cutting edge so as to wash out all chips from the gun bore along a flute in the drill stem. The barrels are drilled to a diameter of 0.289 inch within a tolerance of 0.0005 inch, and with not more than 0.004 inch runout from one end of the 24-inch long barrel to the other.

Reaming cuts are then taken in the barrel bores in a machine somewhat similar in design to the drilling machine shown. In the reaming operations, however, the barrels are mounted on a carriage and are pulled along the reamers, the stem of the reamers being slipped through the drilled hole in the barrels and attached to the headstocks, while the work carriages are fed away from the headstocks. In the drilling operation, on the other hand, the gun barrels remain in one position and the drill heads are fed to them.

Four-flute reamers are employed, and oil under heavy pressure is fed through a hole in the center of the reamers to the cutting end for washing all chips from the bore. Five reaming cuts are taken, two roughing and three finishing. The last reamer removes stock to a maximum depth of 0.0005 inch. The reaming cuts are taken at a feed of 5 inches a minute. Floating chucks are used to permit the reamers to follow the drilled bores.

Drilling Forty-millimeter Anti-aircraft Gun Barrels.—After a preliminary turning operation the barrels are drilled the full length in a gun drilling machine of the type shown in Fig. 11, which accommodates two barrels at one time. A single-lip tool of the gun drilling type is used to drill the barrels for their full length. The bar to which the drill is

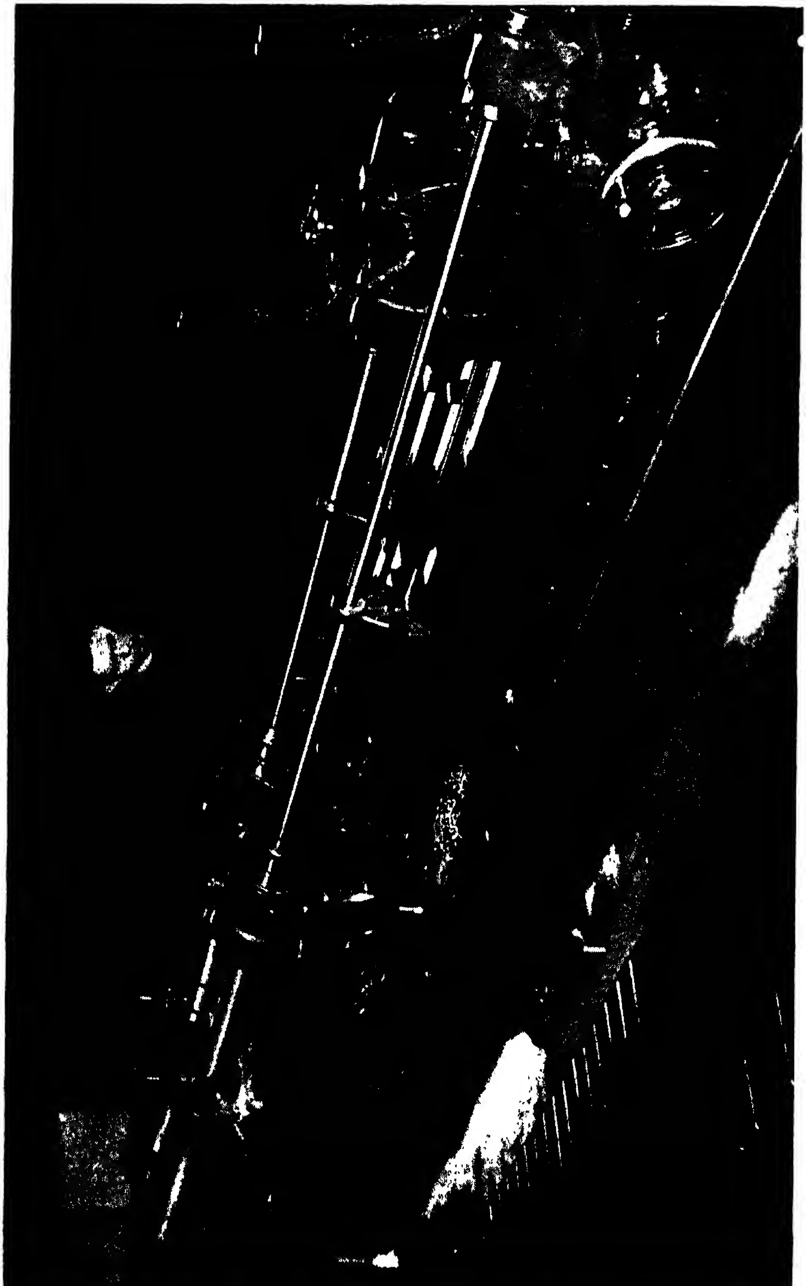

Fig. 11. Drilling Two Anti-aircraft Gun Barrels for their Full Length in a Gun Drilling Machine

attached is provided with a channel on the under side through which the chips are washed out of the barrel by cutting oil that is supplied at a pressure of 200 pounds per square inch. The oil is forced to the drill cutting edges through a 3/16-inch hole in the center of the bar and the bit.

Drilling of the barrels is performed at the rate of 0.0011 inch per revolution of the barrel, the latter being run at a speed of 142 R.P.M. The drill is stationary, as is usual in gun drilling practice.

From the drilling operation, the gun barrels are returned to the lathe for additional turning cuts in which the external surfaces are machined to within 3 millimeters (0.1181 inch) of the finished diameters. The barrels are next bored.

Drill Points for Deep-hole Drilling.— Fig. 12 shows drills that have been ground in accordance with recommended practice for deep-hole drilling. Fig. 13 indicates the angles and other details of the drill point that have been found most advantageous for general use. The information which follows was contributed by F. O. Hoagland.

Dimension *A* should be 1/8 inch for drills about 1/4 inch in diameter; 3/16 inch for drills about 1/2 inch in diameter; and 1/4 inch for drills about 3/4 inch in diameter. A single-lip deep-hole drill will cut a hole close to the size of the drill, whereas the conventional twist drill is likely to cut over size, since it is difficult to grind the two lips exactly alike. As shown in Fig. 13, the "bevel" *B* on a deep-hole drill should be from one-third to one-half the width of the cutting lip. If the "bevel" is made narrow, there is a tendency for the drill to cut over size; if the "bevel" is very small, the drill will vibrate and literally get out of control. The angles suggested are for the average run of work in medium-hard steel. They may be increased by 20 per cent for drilling mild steel, and decreased by the same amount for drilling alloy steels.

In a deep-hole drill, the chip groove is cut to the center of the drill, and it is therefore impracticable to sharpen the drill so that the "bevel" reaches the exact center. On this account, a "flat" having an angle opposite to that of

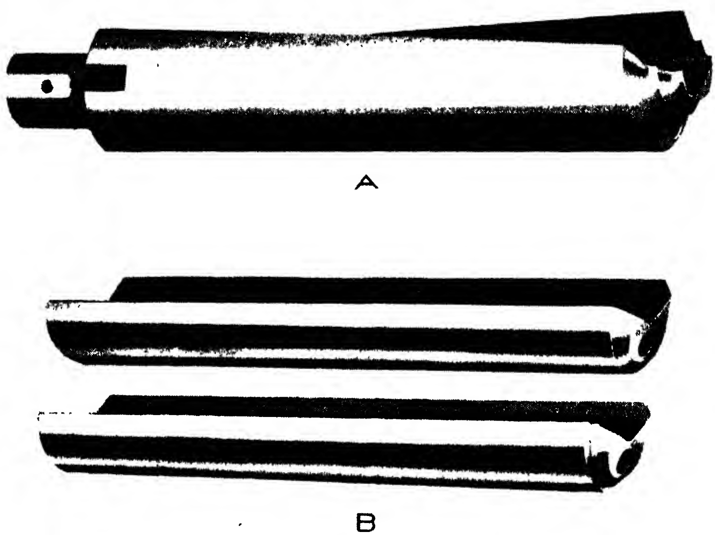

Fig. 12. General Appearance of Drills Properly Ground for Drilling Deep Holes; Drill for Larger Holes is Shown at A, and Two Styles of Grinding for Drills of Smaller Sizes at B

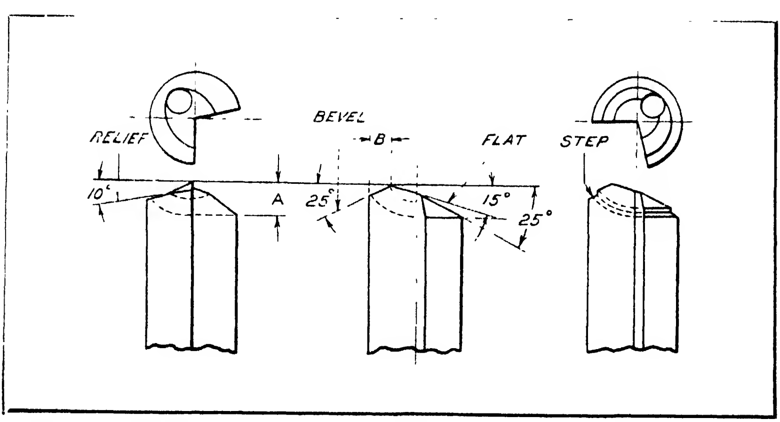

Fig. 13. Angles Used on the Points of Deep-hole Drills for Drilling Medium-hard Steel. For Mild Steel, Increase 20 Per Cent; for Alloy Steels, Decrease 20 Per Cent

the "bevel" is produced, so as to make sure that the heel of the cutting lip is below the cutting edge. Incidentally, this also provides for a generous passage of oil into the chip groove to lubricate the cutting edge and remove the chips.

The "stepping" of the drill point splits up the chip and facilitates its passage through the chip groove in the shank. It aids in producing smoother holes and increasing the life of the drill between sharpenings. In sharpening by hand, the practice has been to use fairly soft and coarse-grit wheels without a coolant. A fine-grit wheel has seldom or never been used, because, when running dry, it has a tendency to burn the cutting edge of the drill.

The cutting edge of the drill must be as smooth as possible. A fine-grit wheel should be used on the drill sharpening machine for finish-sharpening, or the cutting edge should be honed after being sharpened. A smooth cutting edge may increase the life between sharpenings as much as 100 per cent. The oil-hole in the drill should always be cleaned out after sharpening.

Small drill tips are welded to their shanks, but on larger sizes of drills the tips are made detachable, because the long and heavy shanks are cumbersome to handle during the sharpening operation.

So far, we have considered drills for drilling solid metal. At times, however, it becomes necessary to drill long steel tubes having relatively small cored holes. In that case, the drill, if sharpened as shown in Fig. 13, would have a tendency to follow the center of rotation of the work; whereas, if pointed, to let a portion of the "bevel" enter the cored hole, it would tend to follow the hole.

Boring with Standard and Special Machines

When a drilled or bored hole is enlarged, the operation may be classed either as boring or reaming, depending upon the type of tool used. If a single-point tool is used, as in a lathe or boring machine, the operation is always known as boring. Cutter-heads having two or more single-point tools may also be used for boring. For example, when cylinders are machined by using a cutter-head having two or more single-point tools to distribute or equalize the work of cutting, the operation is known as boring and a horizontal type of boring, milling and drilling machine generally is used for cylinders of medium and large size. When a hole is enlarged by using a reamer, the machining operation also serves to enlarge a hole but the operation is classed as reaming. In boring, the cutting tool (or tools) is supported independently of the work, as by the tool shank or a boring-bar, whereas a reaming tool is designed to support and guide itself to a considerable degree by the machined surface.

Some machine tools are designed expressly for boring operations, but many such operations are performed on machines such as lathes, turret lathes, and horizontal boring, drilling, and milling machines. Regular boring machines may have (1) a single spindle; (2) two opposed spindles for operating on both sides simultaneously; or (3) several parallel spindles for such operations as boring all of the holes in a cylinder block at the same time. This section includes machines designed primarily for boring, and also examples of boring on other types of machine tools. "Vertical boring mills" (or "vertical turret lathes," as some designs are called) are not included in this section because

they are used extensively for turning, as well as for boring, and belong to the lathe family, even though they may not be referred to as lathes as a general rule. (See section "Operations on Machine Tools of the Lathe Type.")

Boring Aircraft Propellers.— Aircraft propellers are being bored by the use of the single-end precision boring machine shown in Fig. 1. The operation consists of boring a gun-bronze bushing by removing from 0.008 to 0.010 inch of stock on the diameter. The feed per cutter-spindle revolution is 0.002 inch, and the length of cut is 2 3/8 inches. The hourly production, based on an efficiency of 80 per cent, is twenty-five propellers. The cutter-spindle runs at 1800 R.P.M.

The angle-plate type of fixture provided on this machine is fitted with a hardened and ground ring for locating the hub end of the propeller in relation to the cutter. Strap clamps, locked by tightening hexagonal nuts, are employed to hold the propeller hub securely. The propeller blade is normally supported at its outer end by a bracket mounted on the machine table.

Example Showing Application of Double-head Boring Machine.—The precision boring machine shown in Fig. 2 is being used for the accurate finishing of a control transmission case. The part is a magnesium casting. Two holes are bored in line in one set-up, and then the position of the casting is changed to bring another set of holes in line with the tools. In each case, a bore is finished from a cored hole by both heads within a tolerance of plus 0.0005 inch minus nothing. One tungsten-carbide cutter is provided on each boring spindle.

Machining Opposing Bores with Double-head Machine.— The precision boring machine shown in Fig. 3 is set up for the accurate finishing of bearings in line. The operation illustrated consists of finishing opposing bores in pinion bearing cages, such as the one seen at the front of the machine.

Both bores must be finished to from 3.7480 to 3.7485 inches in diameter, and must be in line within 0.0002 inch

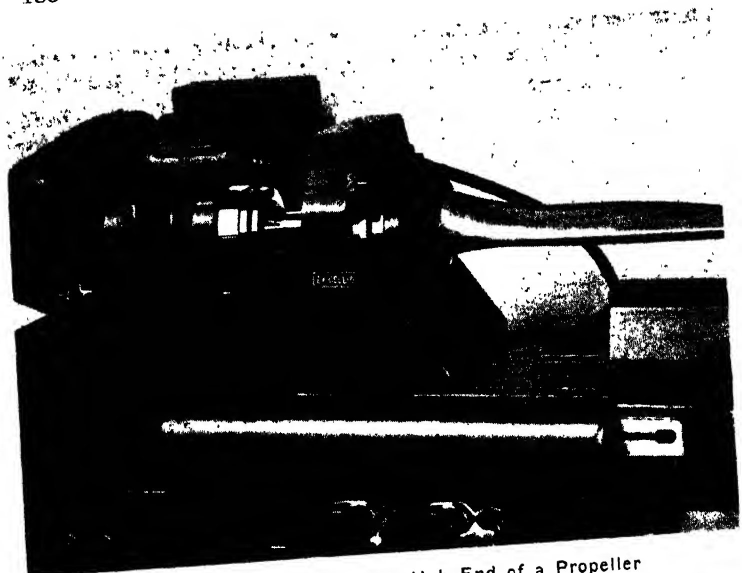

Fig. 1. Precision-boring the Hub End of a Propeller

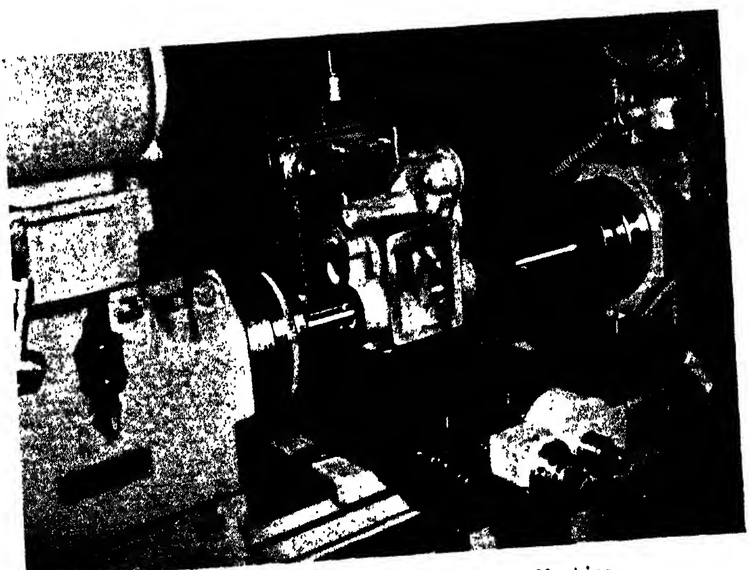

Fig. 2. Alignment Boring on Two-head Machine

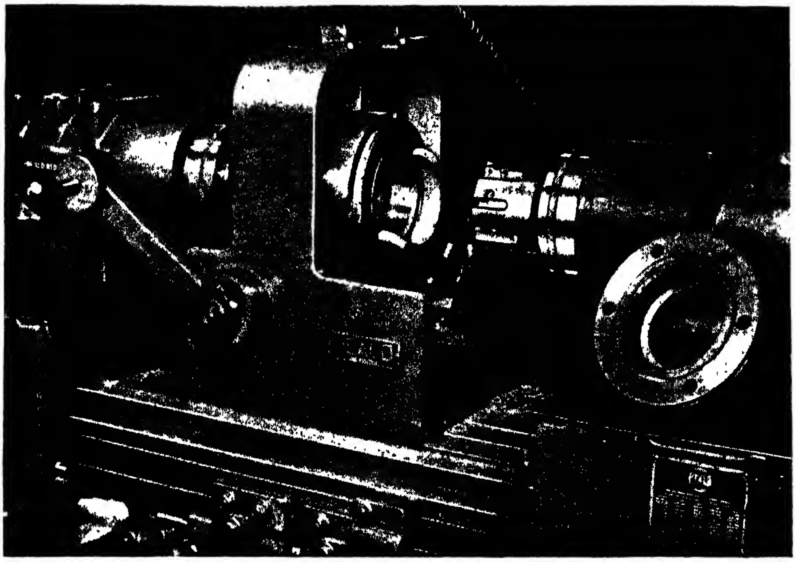

Fig. 3. Simultaneous Finishing of Accurate Bores in Pinion Bearing Cages

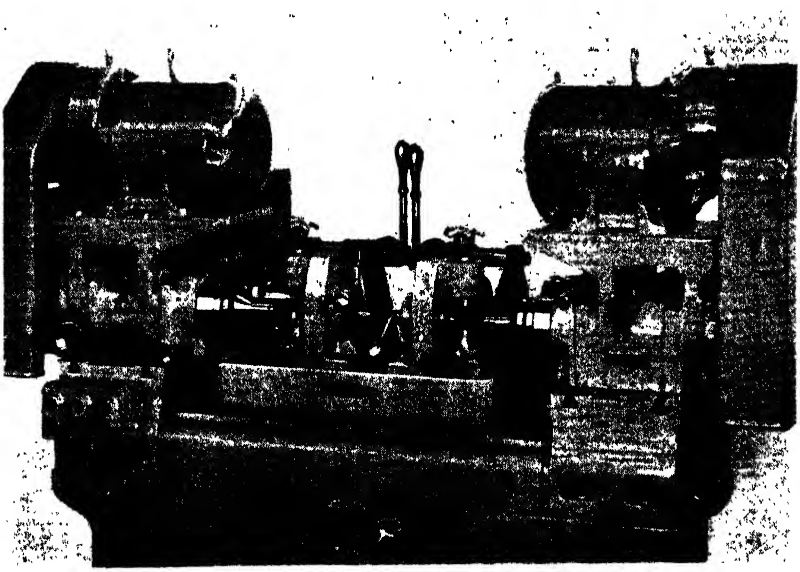

Fig. 4. Finishing Both Bores of Connecting-rods Simultaneously

for their entire length. The dimension from the bottom of each bore to the face of the flange is held within 0.004 inch. Each boring head is provided with two cutters, one of which takes the boring cut and the other a facing cut at the bottom of the bored surface.

Double-end Machine Equipped with Two-station Type of Fixture.—Steel-forged connecting-rods are finish-bored at both ends simultaneously by means of the double-end precision boring machine illustrated in Fig. 4. This machine is equipped with a two-station manually operated fixture, so that a part can be bored at one station while another part is being bored at the opposite station, the machine being so arranged that the table feeds alternately to the right and left for carrying connecting-rods to the heads on both ends of the machine. The hourly production is sixty connecting-rods, based on an efficiency of 80 per cent.

The connecting-rods are located at the small end with a locating plug. They are clamped on top by turning a ratchet hand-knob, and on the bottom by a spring jack. The large end of the connecting-rod rests on a ground pad and is clamped on the face by means of an equalizing strap.

The large end of each connecting-rod is bored to a diameter of 2.436 inches with the spindle running at 140 R.P.M., while the small end is bored to a diameter of 1.045 inches with the spindle running at 324 R.P.M. Both spindles are fed at the rate of 0.016 inch per revolution and remove from 0.015 to 0.020 inch of stock on the diameter. The length of both bores is 1 5/8 inches.

The precision boring machine shown in Fig. 5 is equipped with a fixture that can be loaded on one side while a part on the opposite side is being bored. The work-pieces are hinge type bearing supports in which the hole is held within a tolerance of 0.0005 inch, as required for the assembly of a ball bearing. The machine operates continuously, the fixture being fed first to one spindle head and then to the other (not shown but located at left-hand end of the machine). The handle at the front of the fixture operates both clamps, loosening one while tightening the other, thus greatly speeding up the operation.

Boring Holes at Right Angles on Double-head Machine.— Two operations are performed with the precision boring machine illustrated in Fig. 6 by mounting two airplane flap control parts on the work-fixture. These flap control parts are cast in two pieces and bolted together before com-

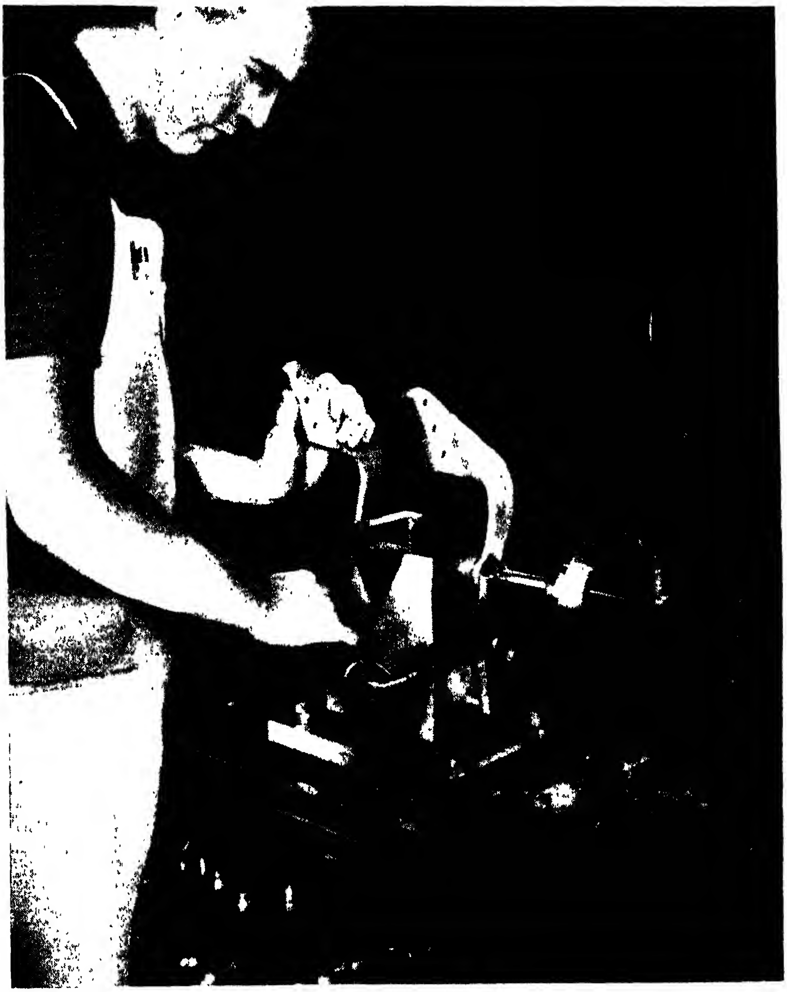

Fig. 5. Fixture for a Precision Boring Machine which can be Loaded on One Side while a Part on the Opposite Side is being Bored

ing to the boring machine, the joint faces having been previously finished on a disk grinder. The castings are of duralumin.

Each part is mounted horizontally on the fixture, as seen at the right, for boring a bearing 1.125 inches in diameter with tools on the right-hand boring-head. The part is accurately located by seating previously drilled and reamed bolt holes of the flange on dowel-pins projecting upward from a steel plate that is clamped to the fixture by operating a small handle. Tungsten-carbide tools take roughing and finishing cuts.

The part is then transferred to the left-hand end of the fixture for boring a hole the same size in the same end of the work but at right angles to the bore just finished. The dowel-plate on which the part was mounted for the first step in the operation is transferred with the work for hold-

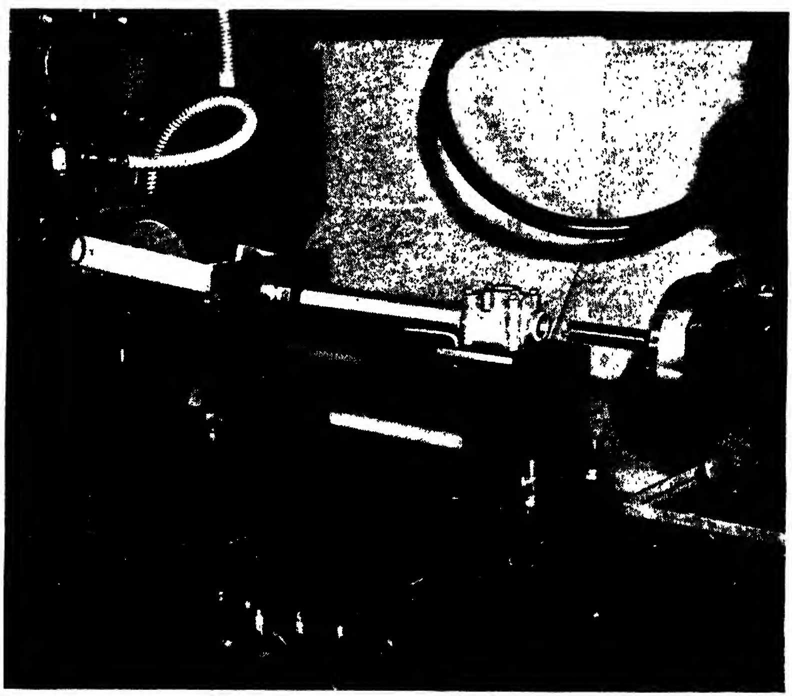

Fig. 6. Precision-boring Holes at Right Angles to Each Other

ing the part in the second step. A tolerance of plus 0.0004 inch minus nothing is specified on the two holes, and one of them is machined to a shoulder, the distance of which from the end of the piece must be held within plus or minus 0.002 inch. This method has eliminated work rejection, which formerly ran as high as 40 per cent when drilling, boring, and reaming were performed, due to distortion of the comparatively light castings.

Boring Strut of Airplane Landing Gear.—The boring operation shown in Fig. 7 is on the strut of an airplane landing gear. This operation consists of boring the oil chamber, the cylinder portion, and two surfaces that are later threaded, there being four different diameters. This operation is performed on a hydraulically actuated machine. For boring struts of different lengths, tool-bars from 72 to 108 inches long are used. They are fitted with tungsten-carbide cutters. The work is held stationary during the operation, and the tool-head is moved hydraulically toward the fixture to feed the revolving boring-bar through the work.

The boring-bar is passed completely through the work before any cutting starts, so that it can be piloted in a bushing of the tailstock seen at the left. Cutting oil is fed to the cutters through the inside of the boring-bar to wash out all chips from the work. Forty gallons of oil are pumped per minute.

After rough boring, the struts are taken to an engine lathe for turning two locating surfaces on the outside concentric with the bores. Finish-boring the oil chamber and the cylinder bore then follows. The tolerance on the diameters is 0.002 inch, and the concentricity must also be within 0.002 inch, as determined by an indicator reading. This close concentricity tolerance is specified in order to insure uniform wall thickness. For this important boring operation, the strut is held in hardened and ground locators. Tungsten-carbide tools are used.

Four-station Machine for Boring and Turning Tractor Pistons.—A precision boring and turning machine is shown

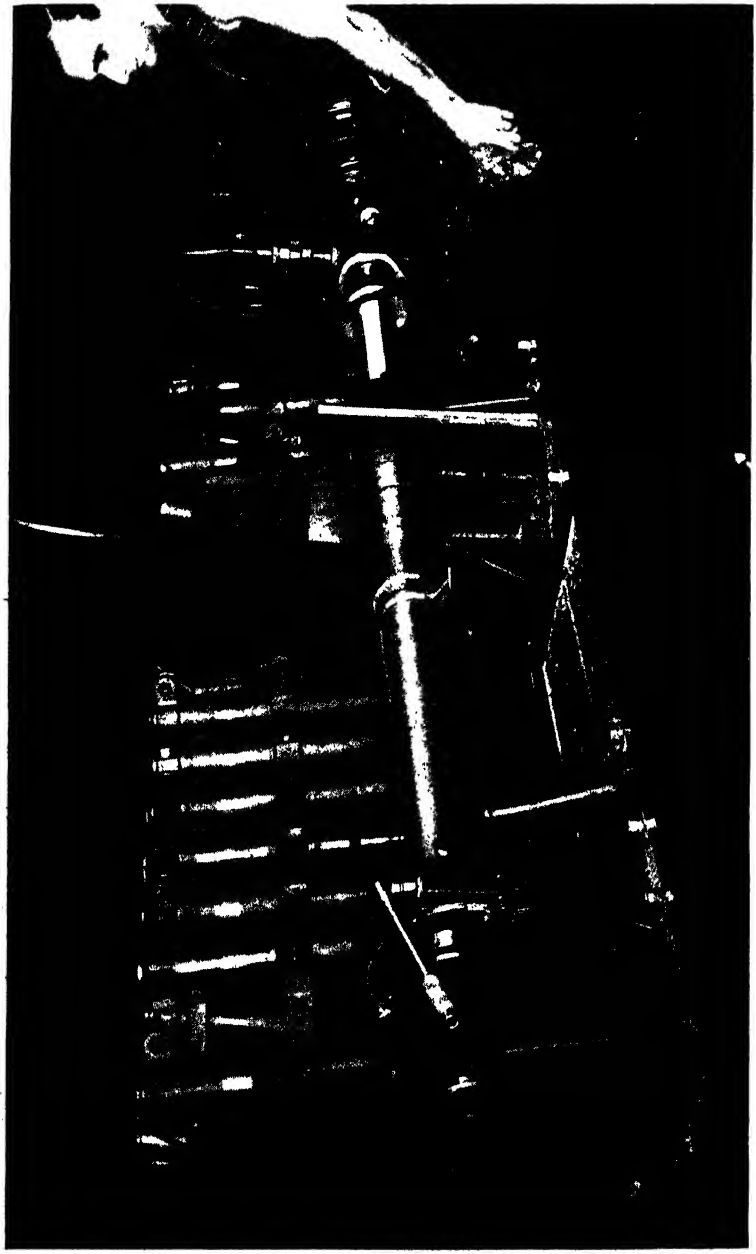

Fig. 7. Finish-boring Four Diameters at One Time on a Machine Equipped with a Hydraulically Actuated Tool-head

in Fig. 8 taking a variety of finishing cuts on tractor pistons. When the pistons reach this machine, they have been rough-machined all over, with the exception of the crater. The crater is finished in the right front position of the machine by a tool mounted in a holder that swings it across the closed face of the piston at the proper radius. The piston is then transferred to the rear position at the right-hand end of the machine, where the ring grooves are finished and the flat portion of the closed end is faced by seven cutters mounted on a slide.

The piston is next transferred to the left front of the machine, where the outside diameter is turned as the table advances toward the left. Then the piston is transferred to the rear left position, where both pin-holes are accu-

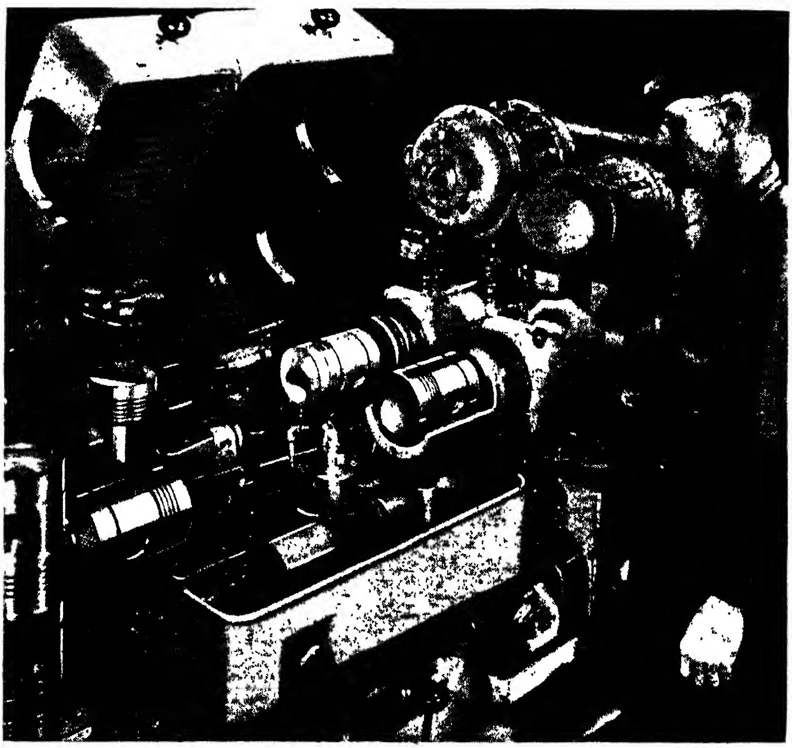

Fig. 8. Four-station Precision Boring and Turning Machine in which Tractor Pistons are Finish-turned, Grooved, Bored, and Faced

rately bored in close alignment. To locate the piston properly for this operation, a bar is passed through the pin-holes and then fingers on the work fixture are swung forward into contact with the bar. With the fingers properly registered, the clamp is tightened on top of the piston, after which the fingers are swung out of the way and the locating bar is removed.

The pin-holes are bored by tools on a spindle mounted in the left-hand head, at the same time that the piston in the left front station is being turned. In the first three stations, the pistons are mounted on the head spindles, while in the last station the piston is mounted on the table.

Example of Boring on Horizontal Type of Machine.—The machine shown in Fig. 9 performs two boring operations, the second one being illustrated. The first operation

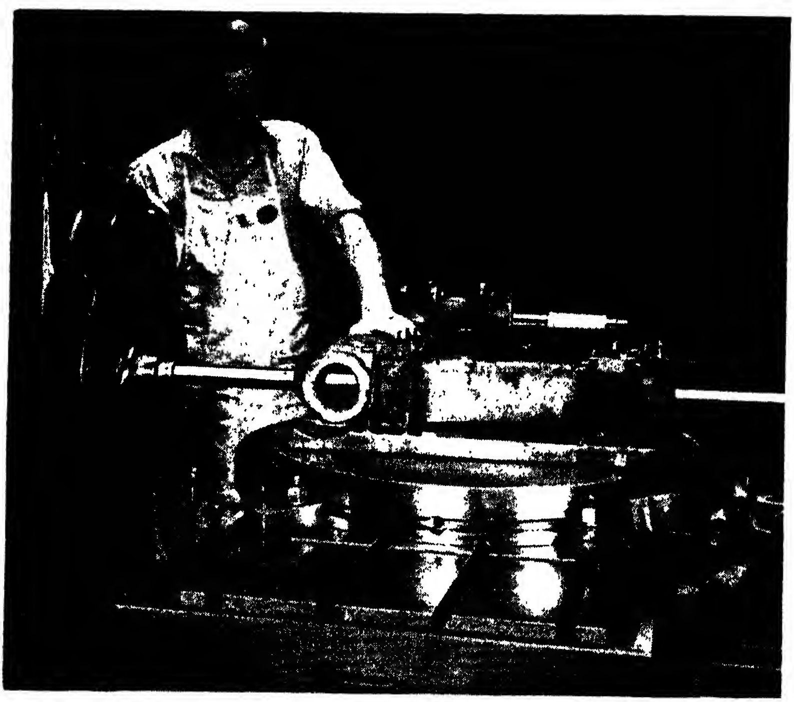

Fig. 9. Welded Landing Gear Fulcrum being Accurately Bored, Faced, and Milled on a Horizontal Boring, Milling, and Drilling Machine

consists of boring a hole 3.750 inches in diameter in an airplane landing-gear fulcrum to provide a tight metal-to-metal fit for an oleo strut. (In this particular case, however, a work-holding fixture is employed.) The hole had to be held to size within plus or minus 0.001 inch. After the hole had been bored, the boss surrounding one end of the hole was faced. In the boring operation, a fly cutter was used to obtain accurate location of the hole, and then a milling cutter made into a reamer was employed to finish the hole.

When this first bore is completed, the table of the boring mill is indexed through 90 degrees to bring the work into the position shown. Bores about 8 inches long are then finished at opposite ends of the arm seen in line with the boring spindle, to a diameter of 2 inches within plus or minus 0.001 inch. Cuts are taken simultaneously on the two ends, and the bores have to be in alignment within 20 minutes. After the rough-boring cut, a bore reamer is used for finishing. Various lugs are face-milled on the same part without changing the mounting of the work.

Hydraulically-operated Swiveling Cutter for Boring Spherical Seat.—Malleable-iron differential cases, such as the one seen at the front of the machine in Fig. 10, are made with a spherical seat that must be precision-bored to obtain the high degree of finish and accuracy required. This spherical seat must have a radius between 2.377 and 2.379 inches. The surface has been rough- and finish-machined when it comes to the machine illustrated, which is equipped with a special chuck in which the case is seated on a large-diameter locating surface. The part is clamped on this seat by means of a hydraulic ram which revolves with the chuck and work.

After the work has been located and the machine started, the table feeds forward to bring a tungsten-carbide tool in holder *A* into the cutting position, at which point the table stops. Then holder *A* is swiveled on a vertical post to carry the tool across the work at the desired radius. Stock to a depth of from 0.008 to 0.014 inch is removed.

When the cut is completed, the table is reversed and the

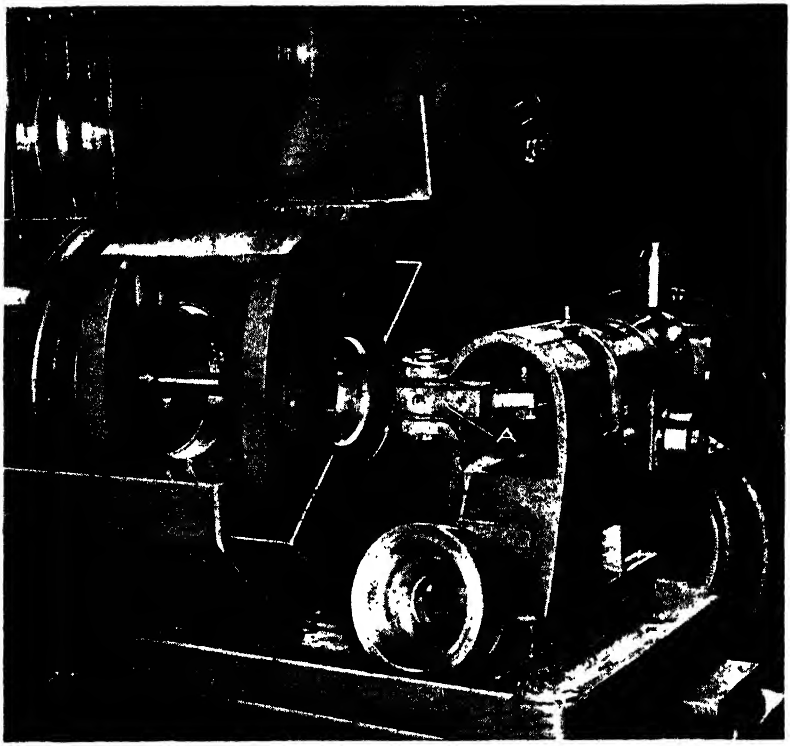

Fig. 10. Ingenious Tooling Arrangement Developed for the Spherical Boring of Differential Cases

tool withdrawn without marring the finished surface. Swiveling of the tool-holder is accomplished through the movement of a crank, which is actuated by a hydraulic cylinder on the tool-head. Oil is admitted into this cylinder when the table strikes a dog at the end of its forward movement, and is released when the table returns.

Spherical Boring with Tool Controlled by Star-wheel Type of Feed Mechanism.—Bearings provided for the crank-shaft journals of certain marine engines of the Diesel type, are castings that are welded into the steel housings, as seen in Fig. 11. This illustration shows an operation on a boring mill in which a spherical surface is being turned in one of the bearings and in its mating cap.

The outer end of the boring-bar is rigidly supported in a fixture mounted temporarily on one side of the bearing. The tool is contained in a holder that is swiveled to feed the tool through the required arc across the spherical surface. The feeding action occurs each time that an arm on the star-wheel, seen in the right foreground, strikes the bar extending from the left, which is mounted on the engine bed. Seven revolutions of the boring-bar are required to impart one revolution to a nut mounted on a feed-screw

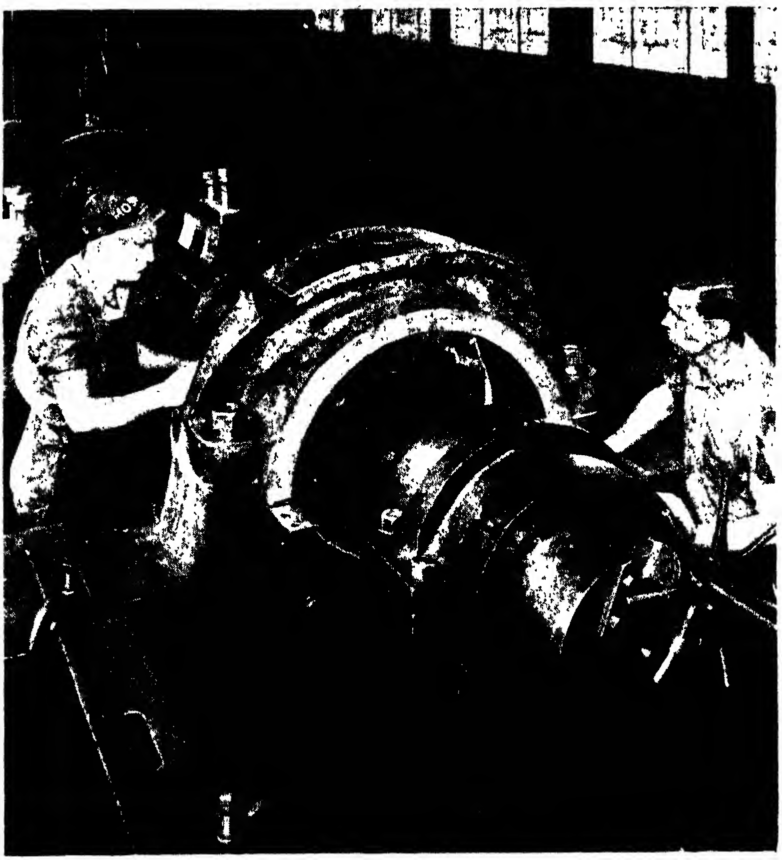

Fig. 11. Boring a Spherical Bearing in the Forward Section of a Large Engine Bedplate to Receive a Member of Corresponding Shape that Supports the Crankshaft

connected to the swiveling tool-holder. With this arrangement, fine feeds can be obtained for finishing the bearing surface to the high degree required. In the operation illustrated, the bearing seat is being finished to a diameter of 33 3/8 inches within plus or minus 0.002 inch.

The structural-steel engine member here being machined is the forward-section bed plate for a 6600-horsepower engine. It is 20 feet long by 13 feet wide by 5 feet high. The bed plate is supported on two tables positioned on the floor plate of the boring mill. There are three spherical bearings on this bed-plate section.

Drilling, Boring and Facing Propeller Hub Forgings.—These airplane propeller hub forgings weigh 275 or 375

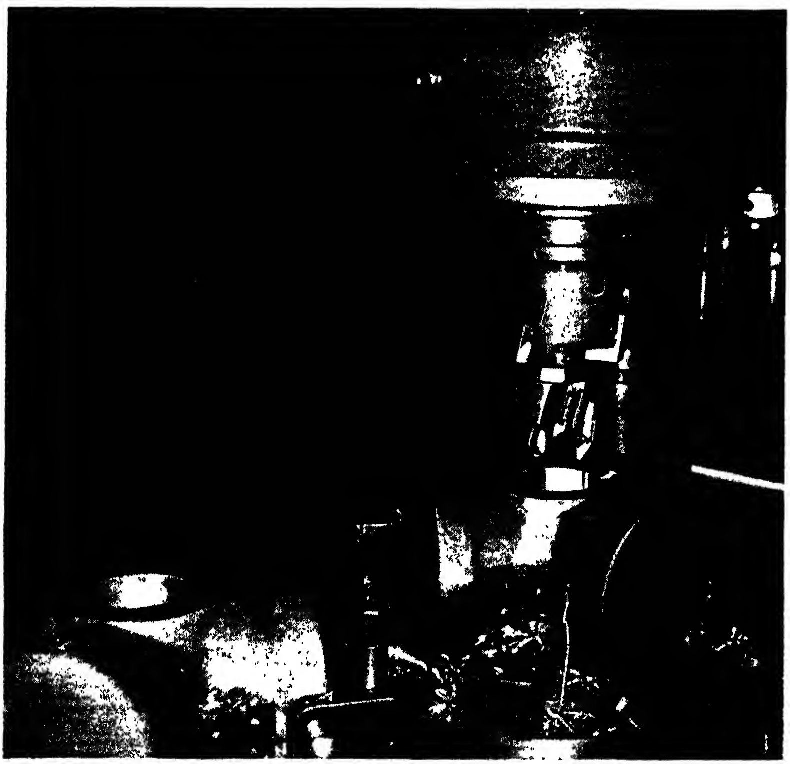

Fig. 12. Drilling, Boring, and Facing Propeller Hub Forgings

pounds in the rough, depending upon their type, and only 57 pounds, within plus or minus 2 pounds, when completely finished. This represents a stock removal of 79 and 85 per cent on the two different types.

The first operation on the hub forgings consists of drilling and boring the cross-bore on the vertical hydraulically operated machine shown in Fig. 12. The cross-bore is produced from the solid, except for a shallow depression in each side of the forging. The first step consists of drilling a 3 5/16-inch hole completely through the cross-bore, which is accomplished with two vertical movements of the drill. Then with a change of tools, rough-boring, rough-facing, and step-boring cuts are taken in sequence. Equalizing chucks are provided on the fixture to insure that the top of the hubs will always be at the same level, despite differences in the length of the forgings. Two chucks mounted on an indexing table provide for reloading while operations are in progress.

Each time the fixture is indexed, four clamps are swung upward on opposite sides to lock it securely to the table. Indexing is accomplished manually, being facilitated by the provision of a ball in the center of the fixture, which raises it for the duration of the indexing movement. With this provision, the fixture can be swung around by a light finger pressure. When the tools are released from the spindle of the machine, they drop on a wooden block that has been placed over the work.

Boring Tractor Engine Cylinder Blocks. — Cylinder blocks for tractor engines are bored to receive the cylinder liners in the machine illustrated in Fig. 13, which is designed to accommodate two blocks at one time. The machine is equipped with two boring spindles on one side, so that two bores of each block are machined simultaneously. Then the cylinder blocks are indexed to bring two more bores into position beneath the spindles. Cylinder blocks containing six bores each are given an additional indexing movement in their passage through the machine.

Lengthwise locations are accurately made by means of dowel-pins, and the cylinder blocks are located sidewise

Fig. 13. Two Bores are Machined Simultaneously in Two Cylinder Blocks with This Equipment. The Blocks are Then Indexed for Machining the Remaining Bores

from the previously milled bearing-lock surfaces. Boring-bars, equipped with three sets of cutter blocks each, are employed. Two of the blocks have cutters for roughing and finishing the bores for the major part of their length, and the third block has tool bits that are necessary for machining a short portion of slightly smaller diameter.

Boring Operations on a Multiple-spindle Drilling Machine.—The boring operation in this case is on the nose ends of shells. The multiple-spindle drilling machine shown in Fig. 14 is equipped for performing three operations on the

nose end. From the loading station at the front of the table, the shells are indexed to the left-hand station where the fuse hole is bored, the end of the shell faced to length and to a conical seat, and the end of the shell chamfered along the outer edge. All the cutters are held on a bar

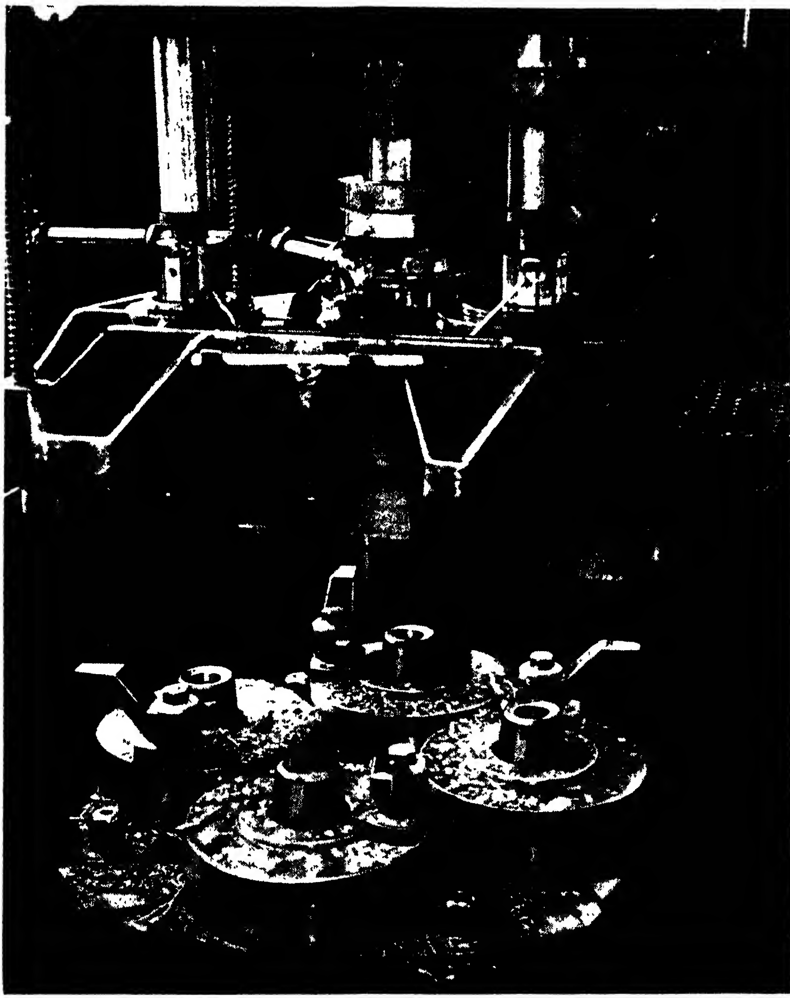

Fig. 14. Boring, Facing, and Turning the Nose Ends of Shells in a Three-spindle Drilling Machine Equipped with an Indexing Table

that is accurately piloted by a large-diameter sleeve on the drill spindle engaging a long bushing in the bushing plate. The cutter-bars of the two following stations are similarly piloted.

In the next working station, at the rear of the table, a "scabbing" cut is taken on the inside of the shell to clean this surface to the end of the bottleneck. The tungsten-carbide tool employed for this cut is fed radially outward as it moves downward into the shell to suit the changing contour of the shell interior. Finally, in the next station at the right, the fuse hole is finish-bored by a tool having eight inserted blades of high-speed steel. Swinging gages mounted on the chucks permit of positioning the heights of the shells as they are loaded in the chucks through the medium of an inserted mandrel contacting the bottom of the shell cavity.

Back-counterboring by Eccentric Movement of Tools.—Back-counterboring of cylinder-sleeve hold-down screw-holes in airplane crankcases as shown in Fig. 15 is performed on a machine of vertical design equipped with a multiple-spindle head and a drum type of indexing fixture. Twenty holes are back-counterbored at one time around a cylinder pad, and there are fourteen cylinder pads on each crankcase. The operation is performed in one-eighth the time required with the method previously in use.

In this operation, the tools are fed through the previously drilled holes and, as they revolve, they move first about an eccentric path until they reach the desired diameter of the back counterbore, after which they revolve about a circle of that diameter to perform the operation. The tools then recede to the center of each hole to permit them to be withdrawn with the next upward movement of the spindle head.

Indexing of the work to bring successive cylinder pads into position beneath the head is accomplished by turning the crank-handle seen at the right. The jig is moved horizontally on the ways of the bed to bring the second series of cylinder pads into line with the tool-head after the first series has been counterbored, and the jig is moved similarly

to place it in the reloading position at the left-hand end of the bed. These horizontal movements of the jig are effected by applying a crank-handle to the square-end shafts seen projecting from the front of the fixture on the right-hand end. The large wheel seen at the lower left is manipulated to open up the fixture endwise for reloading.

Application of Two-spindle Boring Machine to Special Turning Operation.— Fig. 16 illustrates the application of a two-spindle boring machine to the turning of trunnions on reduction-gear carrier-rings. These trunnions are finish-machined before being hardened. They are machined two

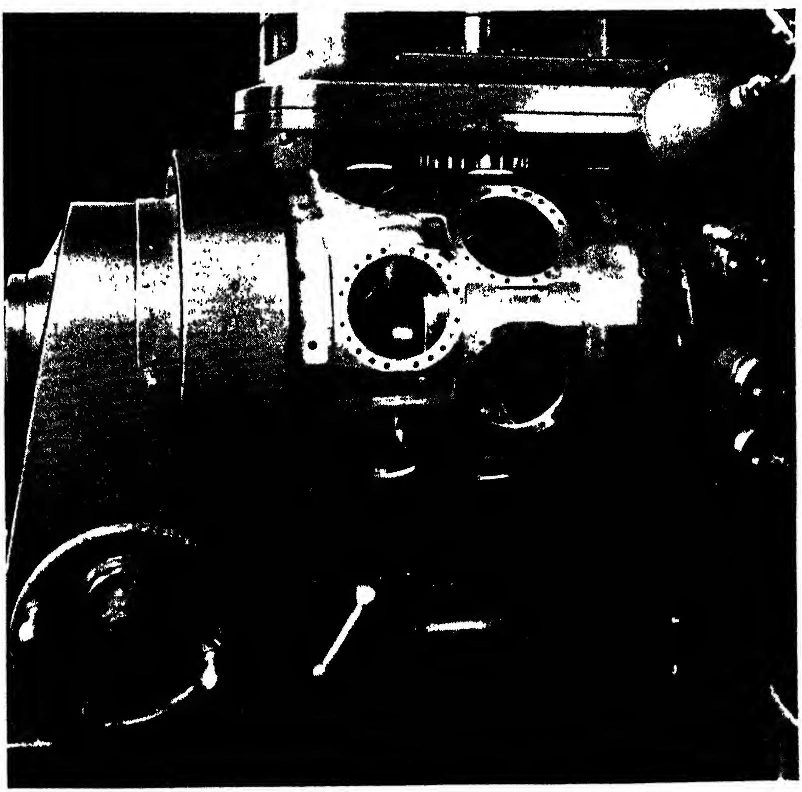

Fig. 15. Machine that Simultaneously Back-counterbores Twenty Hold-down Screw-holes in Each Cylinder Pad on Airplane Crankcases

at a time, and 0.030 inch of stock is removed from the diameter. At the same time, the boss at the base of each trunnion is faced, and a radius is formed at the junction of the boss and trunnion. Carbide-tipped tools are used, and the machining time has been reduced to 11 minutes per part, as against 104 minutes required by the former method, or approximately 90 per cent. On the machine shown, indexing is performed manually, but another similar machine is available in which automatic indexing is employed, which operates without attention from the operator until the part is completed, when it stops until reloaded and restarted.

Fig. 16. Carrier-ring Trunnions are Machined Two at a Time with Carbide-tipped Tools in This Boring Machine

Boring Anti-aircraft Gun Barrel.— The gun-barrel boring machine illustrated in Fig. 17 employs a wood-packed tool bit having two cutting edges for boring the barrel the full length. The wood packs insure firm support of the cutting edges on the tool bit and accurate guidance of the tool from the previously drilled hole. The wood packs are 0.003 inch over size. When they are fed into the breech end of the gun barrel, they are shaved to the exact size of the hole by the sharp edges at the opening of the hole.

The gun is chucked through the spindle of the boring machine, with the breech end held in a three-jaw chuck at the left end of the headstock. Push-boring is done from the muzzle end. The tools are so ground that the boring chips are deflected and washed out at that end. The boring-bar is piloted through a bushing in the housing in which the muzzle end of the barrel rotates. An additional steady-rest supports the boring-bar at a distance of 42 inches behind the boring head. This support is of the sliding type.

The steel cutting edges of the wood-packed bits are so ground that the chips are directed in front of the advancing tool and come out of the muzzle end of the gun barrel, which is nearest the headstock end of the machine. By this provision, any danger of the chips lodging between the wood packs and the bored surface is eliminated.

The cutting edges of the bit are sharpened and the wood packs are replaced after each operation. The boring-bar head is fed hydraulically, advancing the bit through the gun barrel at the rate of about 1/2 inch a minute. The floor-to-floor time for boring the barrel is approximately 3 1/2 hours. In this operation, the gun barrel is revolved at a speed of 165 R.P.M., while the tool bit remains stationary, as far as rotary movement is concerned.

Examples Illustrating Application of Jig-boring Machines.—Machines of the jig-boring type are so designated because they are especially adapted to boring holes in jig plates or in any other class of work requiring accurately spaced holes. One type of jig-boring machine which is extensively used is so designed that adjustments for locating various holes to be bored are obtained by lengthwise

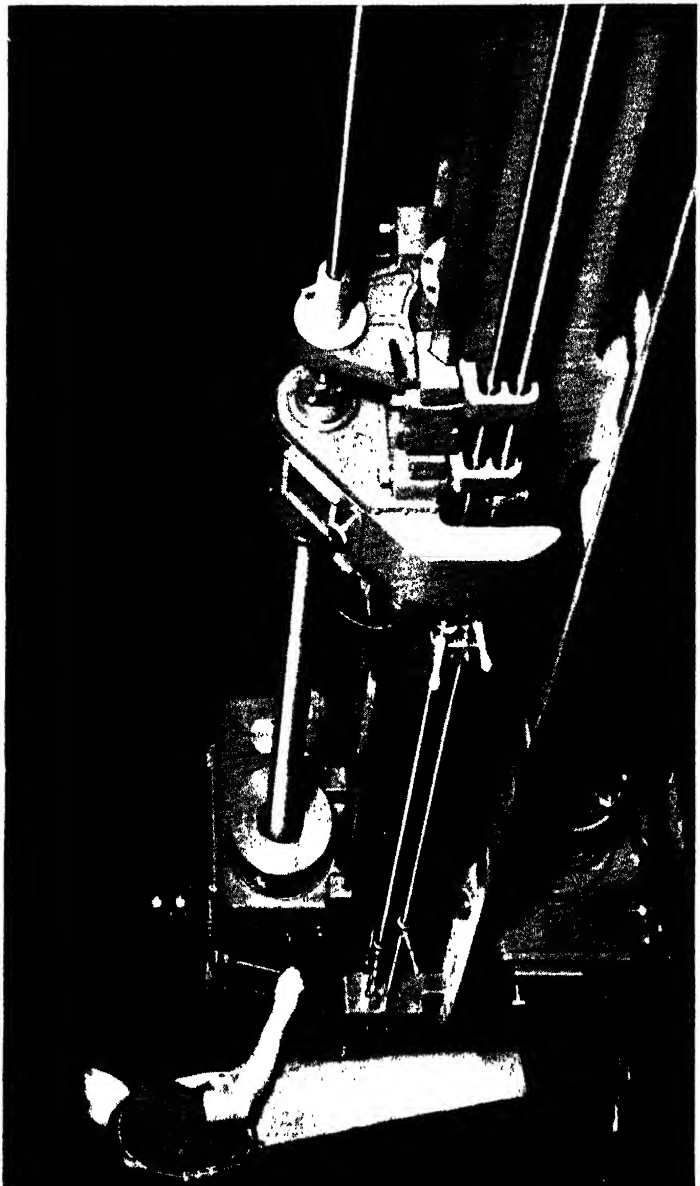

Fig. 17. Boring an Anti-aircraft Gun Barrel the Full Length with a Wood-packed Tool Bit Having Two Cutting Edges

and lateral or cross-adjustments of a compound type of work-holding table. Another design of jig-boring machine has a single spindle adjustable on a cross-rail located above a horizontal work-table which may be adjusted along its bed in a direction at right angles to the cross-rail. With this machine, the work is located in the required position by moving the horizontal work-table lengthwise and the vertical spindle laterally along its cross-rail.

Jig-boring machines are equipped with accurate means of measuring the longitudinal and lateral adjustments for boring various holes to given dimensions within close limits. Some machines have precision lead-screws with micrometer dials. Another type of measuring device consists of vernier scales which show the lengthwise and lateral measurements. A third method consists in using end-measuring rods and micrometers between adjustable stops. To obtain greater refinement and insure uniform measuring pressure for all measurements, contact at one end may be with a dial gage. Linear scales may be used in conjunction with the end-measuring micrometers, for approximate adjustments.

A close-up view of a jig-boring machine is shown in Fig. 18. The operation consists of drilling and boring thirty-two holes around a ring that is later to be cut into eight segments for use on jigs. The machine is equipped with a circular or rotary attachment with suitable indexing mechanism. The radial location of the various holes had to be correct within 1/2 degree, and the hole diameters had to be within plus 0.0000 inch, minus 0.0005 inch of the specified dimensions.

The jig-boring machine shown in Fig. 19 is employed for drilling and boring a series of holes in a jig plate. The tool-head is positioned at an angle on its circular table to present the horizontal tool-spindle correctly to the work. The vertical work-table can be indexed about a complete circle, and can be raised or lowered on the machine column to obtain various heights with respect to the cutter-spindle.

Jig Boring on a Horizontal Boring, Drilling and Milling Machine.—A horizontal boring, drilling, and milling machine is shown in Fig. 20 being used for drilling and boring

Fig. 18. Employing a Jig Boring Machine for the Accurate Drilling and Boring of Thirty-two Holes around a Ring that is to be Cut into Segments

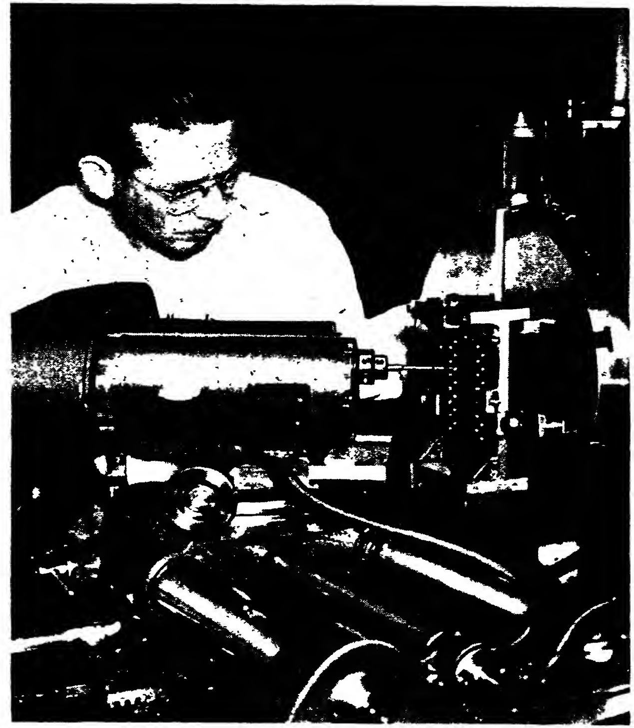

Fig. 19. Performing a Series of Accurate Drilling and Boring Steps on a Small Jig Plate by the Use of a Jig Boring Machine

eighteen holes in a jig member required in airplane building. The holes were produced at an angle of 7 degrees 1 minute relative to the side surfaces of the jig part, and the holes on opposite sides of the jig were machined to opposing angles. The circular table of the machine facilitated making the necessary angular settings. In starting each hole, the operator lined up the machine spindle with a previously laid-out prick mark on the jig member. Then he used a small center drill to start the hole; next a 7/32-inch drill for producing a hole of that size completely through the work, and then a 1 1/64-inch diameter drill for the full length of the hole. Upon the completion of these operations, the drill chuck was removed and an offset boring head

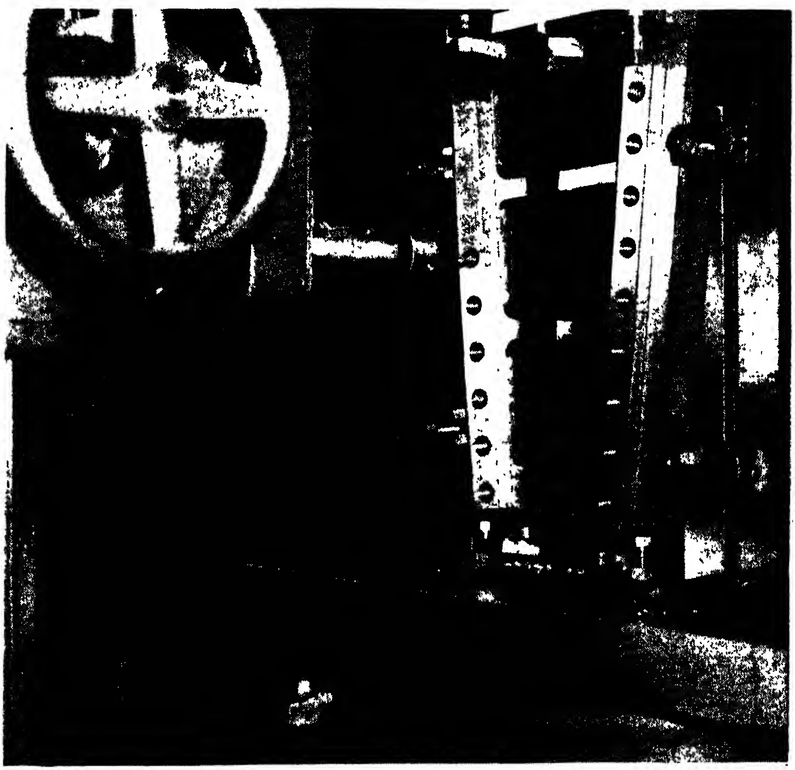

Fig. 20. Jig Boring on a Horizontal Boring, Drilling and Milling Machine

mounted on the spindle, as shown, for finish-boring the hole. The holes on one side of the jig were bored "right on the line" to 1.250 inches, and on the other side to 1.180 inches.

Machines of the general type shown in Fig. 20 are often used for jig boring, especially when the size of the work is beyond the range of regular jig-boring machines.

Rifling Gun Barrels

The formation of helical rifling grooves and ridges in gun barrels, for imparting a rotating motion to the bullet or projectile, may be done by different methods. One method which has been employed extensively for rifling guns of the smaller calibers consists in pulling through the bore a single cutting tool that is wide enough to form the groove. As the cutter is traversed through the bore, it follows a helical path. The method of obtaining this helical movement will be referred to later. The gun barrel is stationary except when it is indexed in order to obtain the required number of equally spaced grooves. The cutter, during each stroke, cuts only a fractional part of the full groove depth. At the end of each return stroke of the cutter, the gun barrel is indexed an amount equal to the circular pitch of the rifling grooves. After the barrel is indexed through one revolution, the cutter is automatically adjusted outward for taking another series of cuts. Thus, the required number of equally spaced grooves are cut gradually to the full depth by a succession of light cuts, each of which is followed by an indexing movement.

The helical path followed by the cutter is obtained on one type of machine from a master bar connecting with the cutter-bar and containing helical grooves similar in lead to the rifling grooves. Another method is by means of a bar having a straight groove or channel which is inclined relative to the travel of the cutter-bar an amount depending upon the required helix angle of the rifling. A roller, which is traversed along with the cutter-bar, engages the groove in the bar, and, through a cross-slide and rack which engages a pinion, imparts a turning movement to the cutter-bar in conjunction with its traversing motion. At the

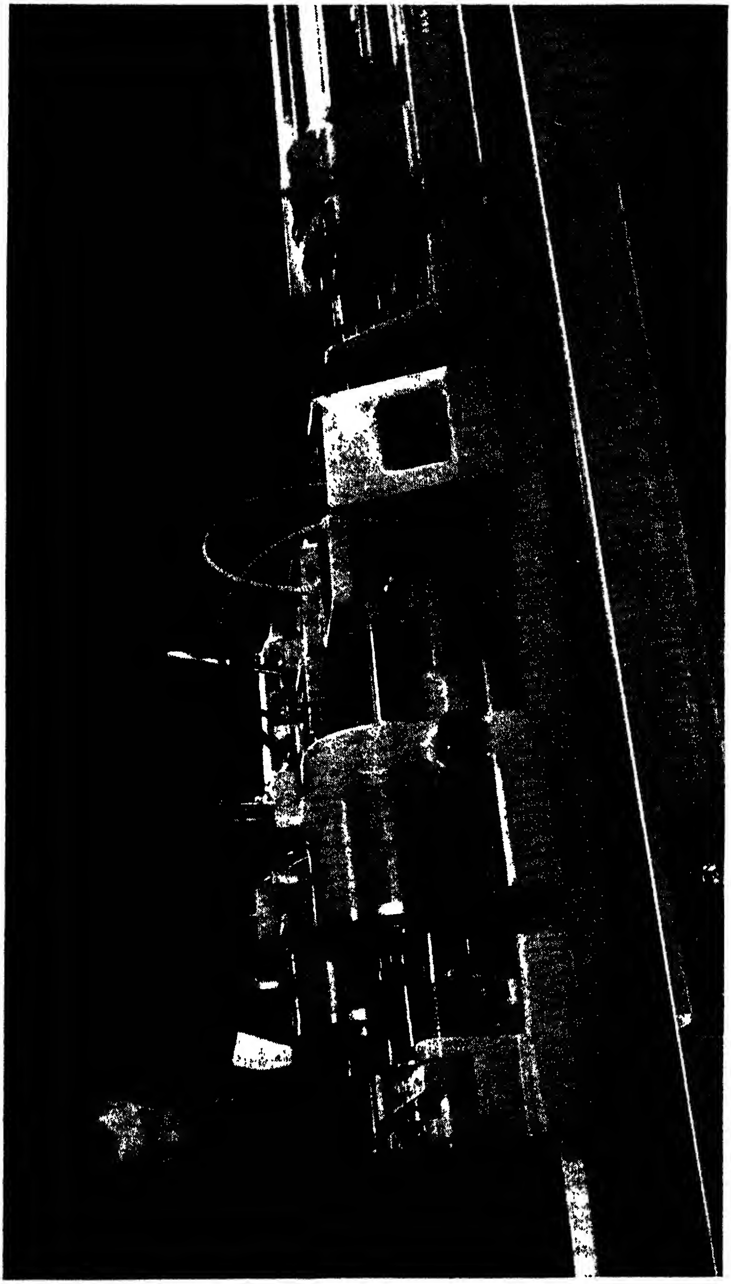

Fig. 1. Duplex Rifling Machine Equipped with Master Lead-screws for Rotating the Rifling Bars to Obtain Rifling Grooves of the Required Helix Angle or Lead

present time, the twist or rifling generally is uniform or of constant lead, although, in some cases, a variable lead is preferred.

A second general method of rifling employs a rifling tool of the multiple-cutter type. The number of cutters on this type of rifling head equals one-half the required number of rifling grooves. These cutters are equally spaced so that the first series of grooves cut have twice the required center-to-center distance. After an indexing movement equal to the circular pitch of the rifling, additional grooves are cut between the first series. This multiple-cutter method is applicable to guns of medium and large caliber.

A third method of rifling is by broaching. This broaching process is similar in principle to ordinary internal broaching. The broach, however, is given a turning movement as it is pulled through the gun bore so that the cutting teeth follow a helical path. Several broaches are required to form the rifling by a succession of cuts. The broaching process is very efficient for work within its range. The examples following will illustrate these different methods of rifling. The method employed in a plant manufacturing guns may depend upon such factors as the size of the bore to be rifled, the equipment available, and also individual opinions concerning the relative merits of the different processes.

Rifling 0.30 Caliber Machine-gun Barrels. — The rifling machine shown in Fig. 1 is used for rifling the barrels of air-cooled 0.30 caliber machine guns. This rifling consists in cutting four grooves the full length of the barrels at a lead of one turn in 10 inches. Prior to loading the barrels in this machine, which handles two barrels at a time, an adapter is screwed on the threads milled on the breech end in the preceding operation. The rifling tool is a new type of hook cutter made from high-grade tool steel and carefully honed and lapped. It is adjusted to remove stock to a depth of 0.0001 inch with each stroke through the barrel. The stem or shank which carries the cutter is slipped through the barrel bore and connected to a carriage seen at the right, which pulls the rifling tool through the barrel.

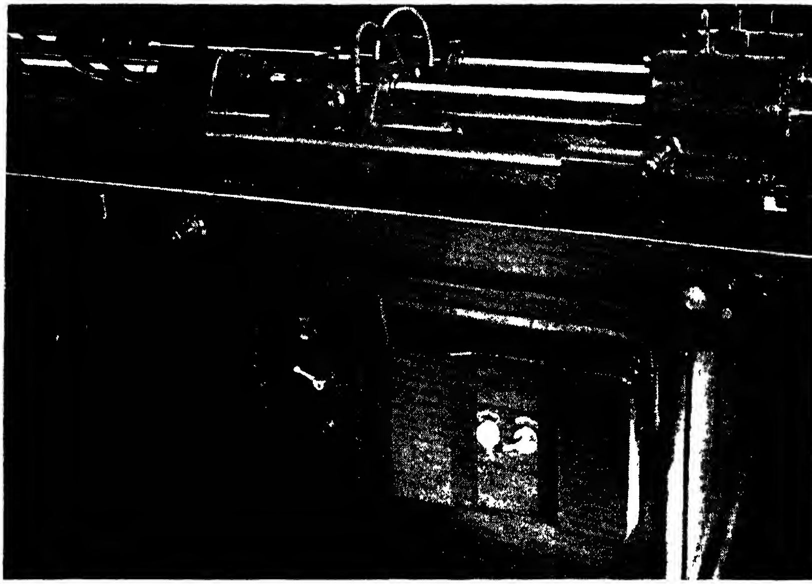

Fig. 2. Duplex Type of Machine Rifling 0.50 Caliber Machine Gun Barrels

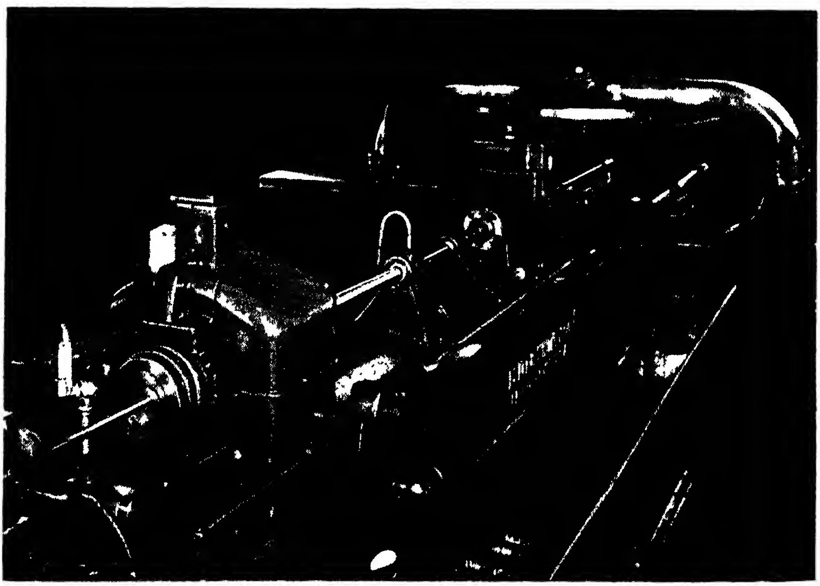

Fig. 3. Another Type of Rifling Machine Fitted with an Angular Bar which is Adjusted to Obtain the Required Helix Angle or Lead

During this stroke, the rifling bar is swiveled to obtain the required helix of the grooves as rollers on a stationary head mounted on the bed of the machine ride along grooves in a lead-screw to which one end of the rifling bar is attached.

Each time the grooving cutter reaches the end of its cutting stroke, a finger depresses it sufficiently so that it will not ride on the rifling groove just machined during its return stroke. Upon the completion of each return stroke, the gun barrel is indexed through 90 degrees, and the cutting tool then repeats its cycle. After every four indexings, the cutter is automatically fed upward 0.0001 inch, ready for taking the next sequence of cuts. About one hundred strokes of the rifling head are required to complete the rifling of a barrel.

The operations on the two sides of the machine are performed independently of each other. The rifling bars are operated hydraulically. Oil is fed through the rifling bars to the cutters, as in the drilling and reaming operations, to wash out the chips. Circular wire brushes mounted on stationary members of the machine revolve in contact with the rifling bars to the right of the gun barrels, so as to wipe off all chips that might mar the rifling grooves during the return stroke of the cutters.

Rifling 0.50 Caliber Machine-gun Barrels.—Rifling of the caliber 0.50 machine-gun barrels is performed after a reaming operation, on machines of the type shown in Fig. 2. This machine is similar in design to the one shown in Fig. 1. Two barrels are rifled at a time by tool-bars attached to the hydraulically actuated carriages. The rifling bars are rotated to produce the desired helix as the lead-screws seen at the left, to which the cutter-bars are connected, are pushed past stationary heads equipped with rollers that engage the threads of the lead-screws.

One groove at a time is machined to a depth of about 0.0003 inch with each stroke of the rifling tool. Upon the completion of each stroke, the barrel is indexed by a mechanism at the right-hand end of the bed, in order to cut eight rifling grooves around the barrel bore. When all the grooves have been machined to the same depth, the small

hook type cutter bit is fed upward 0.0003 inch in the bar, and the process is repeated. About twenty cuts must be taken in each groove, necessitating about 160 reciprocations of the rifling bar in order to complete one barrel. The machine is hydraulically operated, and a barrel can be rifled complete in approximately 60 minutes.

Each cut is taken during the draw stroke of the cutter-bar, and the cutter bit is automatically depressed for the return of the bar through the rifle bore. The rifling bar closely fits the barrel bore. Each time that the rifling tool is withdrawn from the barrel it passes over a motor-driven brush in the unit that supports the left-hand end of the barrel, so as to clean off all chips from the cutter.

Machine Equipped with Sine-bar for Controlling Helix Angle of Rifling.—Barrels for semi-automatic rifles are rifled on machines of the type illustrated in Fig. 3, which are designed with a sine-bar arrangement, by means of which any desired rifling helix can readily be obtained. It is merely necessary to change the angle of the sine-bar in order to vary the twist of the rifling bar. In this machine, the barrel is also indexed between strokes by the mechanism at the front end.

Rifling Anti-aircraft Gun Barrels with Single-cutter Indexing Type of Machine.—In rifling a Bofors 40-millimeter anti-aircraft gun, grooves to form the rifling are machined to a helix that changes constantly at increasing angles from the chamber to the muzzle end of the barrel. The grooves are produced by a tool which removes from 0.001 to 0.0015 inch of stock at each successive pass through the full length of the barrel bore.

Rifling is performed in the machine seen in Fig. 4. A single-point tool is mounted in an auxiliary bar attached to the front end of a master bar, which is revolved at an accelerated rate as the cutter advances through the barrel bore. The practice is to cut the original grooves from the breech end of the gun, which is held in the headstock of the machine, to the muzzle end, which is supported in a combination chuck and indexing fixture, as seen in the illustra-

tion. In other words, the tool is pulled through the gun barrel by hydraulic pressure rather than pushed through it. The indexing fixture is also hydraulically controlled, and is fully automatic. It indexes the work through the distance between two grooves with each return of the cutter to its starting position.

The swiveling of the cutter-bar at the changing rate necessary to obtain the helical path of the rifling grooves is accomplished by a groove in the master bar, the latter being seen in the right foreground. A roller in the unit that supports the master bar in front of the indexing unit rides in this groove and causes the master bar to swivel accordingly, as it is fed in a longitudinal direction.

The groove in the master bar was cut on the rifling ma-

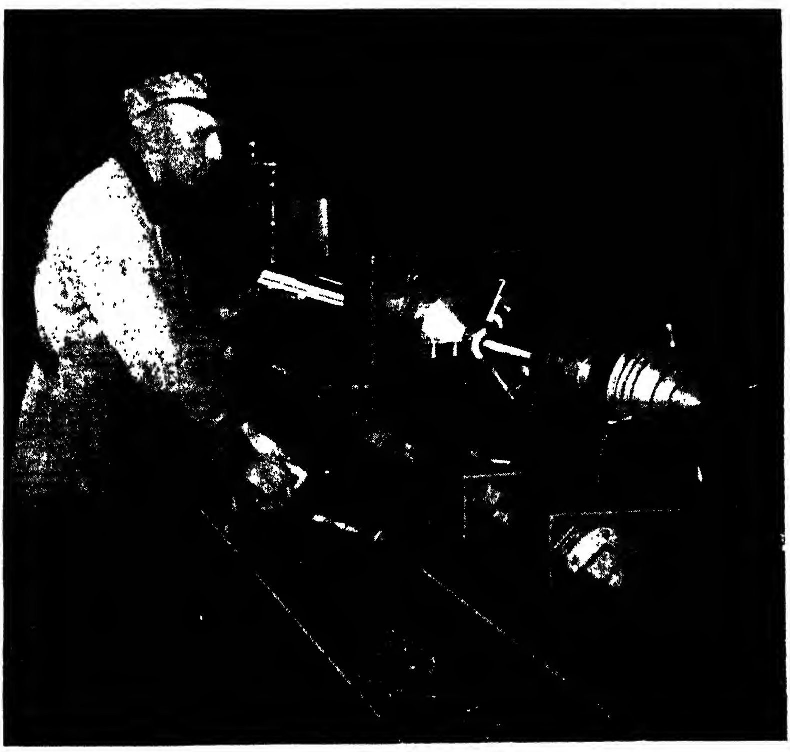

Fig. 4. Rifling Anti-aircraft Gun Barrels

chine by means of a shaper attachment provided with a cutter that removed stock as the master bar was fed past the attachment and, at the same time, revolved in accordance with the curvature of a steel ribbon positioned on the table at the back of the machine. This steel ribbon is carefully set up and clamped on the table to develop the rifling helix on the master bar.

In the rifling operation, the practice is to cut a groove to a depth of 0.001 or 0.0015 inch with one stroke of the cutter, as previously mentioned, and then index the work after the cutter has been returned through the groove to the far end of the gun barrel. A cut of the same depth is then taken in all the grooves, after which the cutter is adjusted to a greater depth and another cut taken in all grooves. This cycle is repeated until approximately twenty cuts have been made in each groove.

The settings of the cutter are adjusted by means of a graduated collar on a head attached to the master bar,

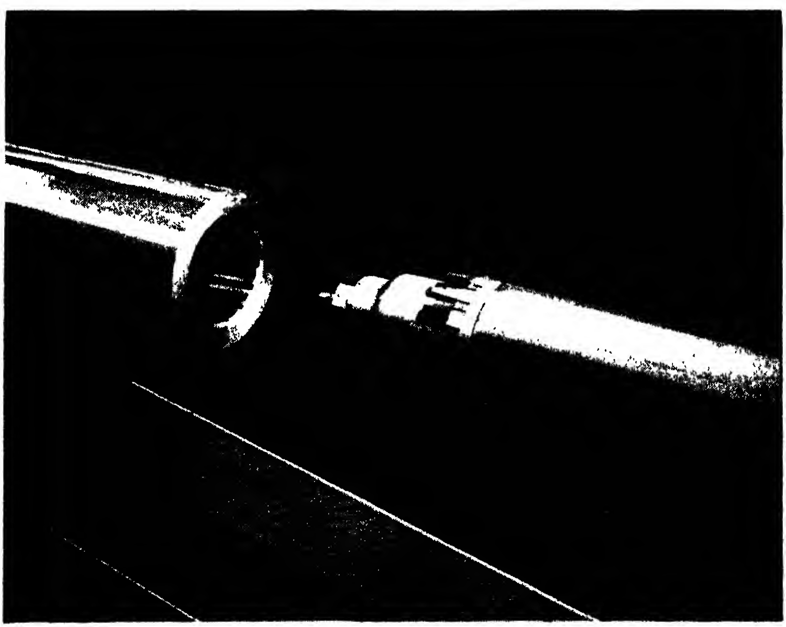

Fig. 5. Rifling Head of the Multiple-cutter Type

there being twenty-five graduations for an adjustment of 0.001 inch. This insures extreme accuracy in changing cutter settings. Each time that the cutter returns through the groove machined during the forward stroke of the master bar, it is automatically receded in its holder, so as to avoid scraping the groove. The outward feeding and receding movements of the cutter are effected by a draw-bar which extends through a hole in the center of the auxiliary bar. Coolant is supplied to the cutter through the hollow master bar and a hole in the auxiliary bar. Brushes immediately in front of the cutter carry all chips to the ends of the gun barrel, a provision that eliminates scoring of the rifling grooves. Four cast-iron strips on the cutter-holder serve to pilot it in the honed bore.

It takes about eight hours to rifle one of these gun barrels. At the end of the operation, "Go" and "Not Go" gages are employed to check the accuracy of the rifling grooves at the two ends of the gun barrel, and gutta-percha impressions are taken of the complete rifled bore.

Rifling 3-Inch Anti-aircraft Guns with Rifling Head of Multiple-cutter Type.—Rifling, which follows a honing operation, is performed on a long lathe of the gun boring type. At the front end of the long boring-bar there is a tool-head of the type seen in Fig. 5. This tool-head is equipped with fourteen cutter bits equally spaced around its periphery for cutting a similar number of rifling grooves with each stroke of the head through the liner. Forty strokes are necessary to finish the grooves, after which the head is indexed one-half the distance between the first series of grooves, for cutting fourteen additional grooves, also in forty strokes of the tool-head. With each forward stroke of the rifling head, stock to a depth of 0.001 inch is cut from each groove for thirty-five strokes and then for the final five strokes the depth of cut is only 0.0005 inch.

During each stroke, the boring-bar is swiveled to cut the grooves to the desired helix, which equals one turn in forty calibers. This swiveling action is obtained by keys in one of the bar-supporting stocks engaging helical grooves machined on the boring-bar. At the end of each forward

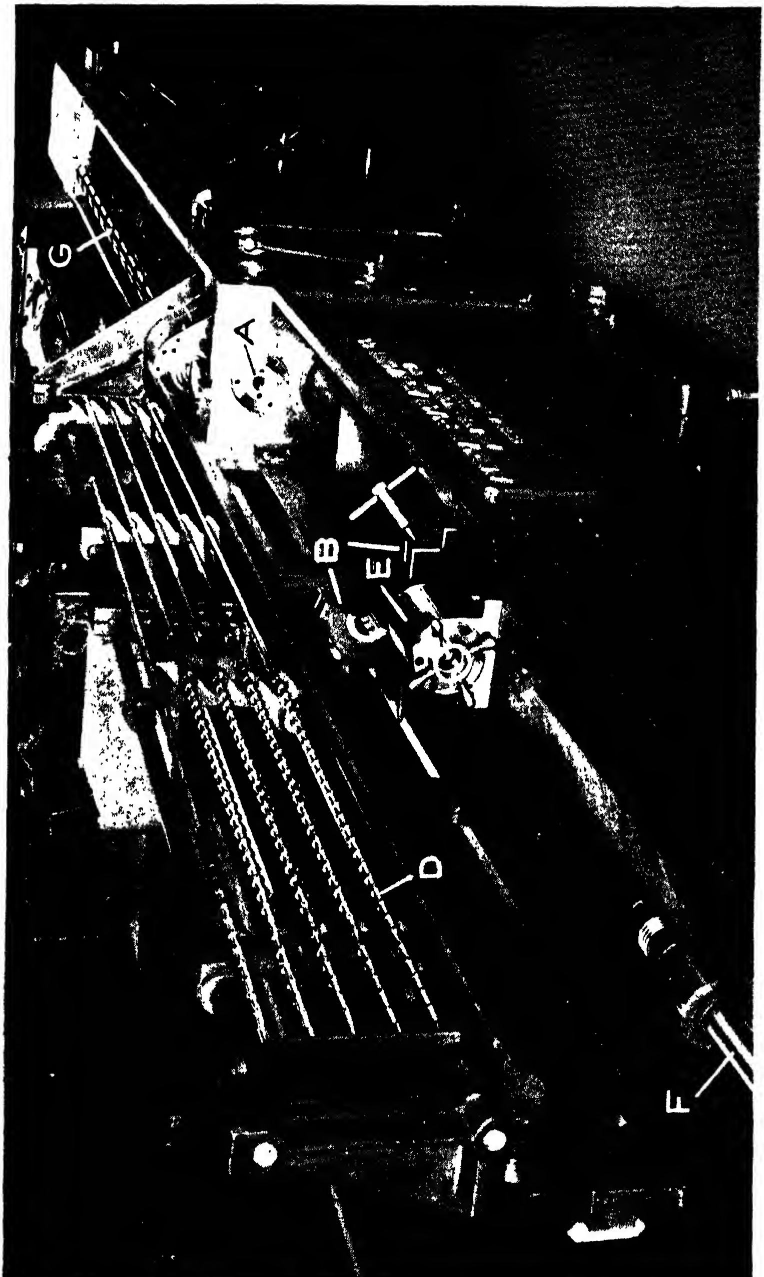

Fig. 6. Hydraulic Pull-broach Rifling Machine Equipped for Rifling 20-millimeter Cannon

stroke a stud on the front end of the tool-head strikes a stop, causing all of the tool bits to recede radially for the return stroke and thus eliminating drag of the cutters in the grooves being rifled. The operator resets the cutters to the desired depth for the next stroke by adjusting a nut on the boring-bar which operates a screw and wedge to expand the cutter bits radially. Piloting lands ahead of the cutter bits hold the tool-head rigidly during a cut. The rifling groove widths must be between 0.1840 and 0.1880 inch when completed.

Rifling 20-Millimeter Cannon by Broaching. — Fig. 6 shows a rifling machine and tools for broaching the helical rifling grooves in 20-millimeter cannon for bombers and for anti-aircraft defense. This hydraulic rifling machine of the pull-broach type will rifle the 20-millimeter bore of the 73-inch long cannon in approximately 10 minutes, floor-to-floor time. The rifling is accomplished by passing four broaches through the bore successively. The small end of the cannon barrel is placed in bushing *A* of the faceplate, and the breech end is located in the quick-clamping rest *B*. The cannon to be rifled is thus centered and held in position for the broaching operation.

The first broach, *D*, is inserted into the bore of the cannon through housing *E*, and oil-tube *F* is slid forward and locked in position. The cutting stroke draws the broach through the work, the spiraling bar *G* imparting to the broach the rotating movement necessary to produce rifling grooves having the required helix angle.

At the end of the broaching stroke, the first broach is removed and returned to the rack which has traveled to the right-hand end of the machine along with the broach. The return stroke carries the pull-head and the broach rack back to their starting positions. The broaching operation is then repeated, using the second broach on the rack. The third and fourth broaches are used in the same manner, the rifling being finished by the fourth broach. The fifth broach, shown at the top of the rack, is a master sizing broach and is only used when the fourth broach shows signs of dullness and is to be replaced by a sharp broach.

The machine is provided with variable-speed control for the cutting stroke. A stroke of 8 feet per minute, however, has been found satisfactory.

The broaches are 48 inches long and have detachable shanks. The teeth are designed to permit the cutting oil to force the chips ahead of the cutting edges and into the chip pockets between teeth without wedging them between the work and the tool. All broaches have a pilot at the starting end, the first broach having a plain pilot, while the succeeding ones have spline pilots for locating them in the proper position to follow the grooves previously broached.

The first broach cuts one-fourth of the width of each groove, broaching all groves at one time and cutting to

Fig. 7. Lapping Machine Gun Barrels after Rifling

practically the full diameter minus a few ten-thousandths inch allowance for the finishing cut. The second broach removes the same amount of stock, taking a cut at each side of the groove cut by the first broach. The third broach, cutting in a similar manner, increases the width of each groove an amount equal to one-fourth the full width. The fourth broach follows the same procedure, with the exception that several teeth at the finishing end cut the grooves to their final width and full depth.

Lapping Machine-gun Barrels after Rifling.—The lapping operation illustrated in Fig. 7 follows the rifling of Bren light machine-gun barrels. The barrels are lapped four at a time in a machine of upright construction, as shown. For this operation, lead laps are produced by inserting steel bars, about 1/8 inch smaller in diameter than the barrel bore, into the bore and pouring molten lead into the barrel. Thus a lap having a minimum thickness of 1/16 inch is produced all around one end of the steel bar, tape having been previously tied around the bar to prevent the lead from running completely down the barrel bore. The lead lap is about 3 inches long. After the lap has been cast, it is withdrawn with the steel bar from the barrel bore by a spiral pulling action. The flutes in the lap are then nicked to insure a tight fit in the barrel bore, after which an abrasive compound is applied to the lap.

In operation, the laps are reciprocated in the barrels through a crank action of the machine and, at the same time, the laps are swiveled backward and forward to impart a spiral motion to them. They are moved up and down at about fifty strokes a minute. Later a cylindrical lap is used to polish the rifling lands and increase the diameter of the bore to 0.303 inch, which is the caliber of the gun.

Preliminary Cutting Operations on Bars, Tubes, and Plates

In the manufacture of certain parts, the first operation is to cut a bar, tube, plate, or sheet to a given length, size or form, this being the initial step in making a part. This cutting-off or approximate sizing or forming operation, usually is followed by one or more operations on some other type of machine tool. For example, a round bar may be cut into given lengths preparatory to centering and turning these shorter sections in some type of lathe; or a plate may be cut into some required shape as, for example, by means of the flame-cutting process to be illustrated later. Many developments have been made in the design of machines for cutting off bars and also for cutting operations on sheets or plates. It is not feasible to include all types of cutting-off and other cutting machines, but some typical examples follow.

Cutting Thirty-five Bars of Stock Simultaneously.—The bar stock from which shells are forged in one munitions plant is purchased in 15- or 16-foot lengths so calculated as to give an even number of shells with minimum waste. Fig. 1 shows the cutting of billets for forging the shells. These billets are cut from bars by a hydraulic sawing machine which is loaded with a number of bars for simultaneous cutting. In the particular operation illustrated, for example, thirty-five bars of steel are cut at one time for producing seventy shells of the 60-millimeter size. The bars are held securely on the carriage of the machine by hydraulically operated vise jaws at the front of the table, and also by an additional hydraulically operated member

which is pushed downward on top of the bars on the opposite side of the saw frame from that illustrated. The bars are supported for their full length by the carriage, which automatically feeds them forward past the saw, upon the completion of each operation, to position them for the next operation. Sawing of the billets provides a clean square end and facilitates proper centering by the first punch of the forging operation.

Sawing Gun Barrel Forgings.—After a straightening operation, certain gun forgings are cut to length, a section being cut off both ends. This operation is performed by the hydraulic shear-cut sawing machine shown in Fig. 2, which cuts off both ends in about one hour. At the end of each cut the saw trips itself and the saw frame is auto-

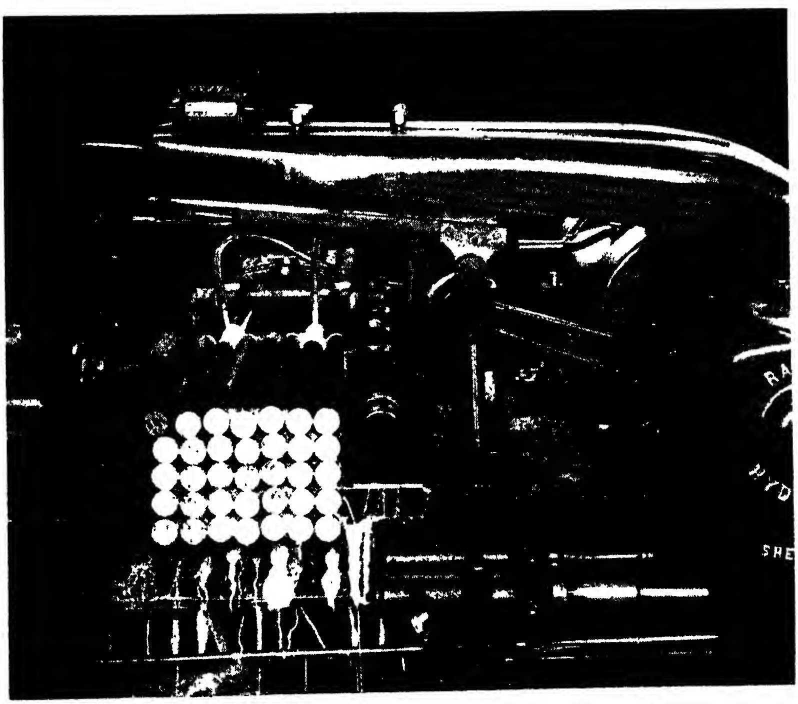

Fig. 1. Cutting Thirty-five Bars of Steel to Length in One Operation

matically raised to clear the work by a hydraulically actuated mechanism. Disks 7/8 inch thick are also cut from the muzzle and breech ends of the forging by a saw of this type for making circumferential physical tests, such as tensile, bending, and Izod impact tests. The test pieces are cut from positions as near the bore of the gun as possible; in fact, the tensile test piece is tangential to the bore. In this way, these tests are conducted on sections comparable to those on the gun barrel that will be stressed when the gun is in use. Disks cut from the barrel forging are etched in hydrochloric acid to determine the grain structure. Chemical analyses were, of course, made before forging was started on samples cast from the melt.

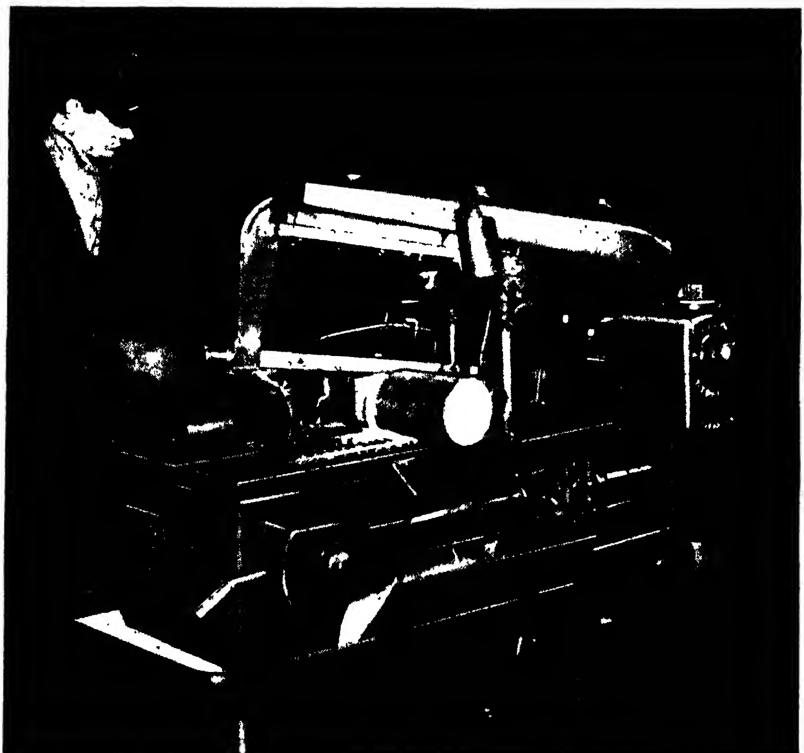

Fig. 2. Hydraulic Saw Employed for Cutting Gun Barrels to Length and for Cutting off Disks of Steel for Making Physical Tests

Sawing Machine Equipped with Two Blades for Cutting Out Surplus Stock.—When surplus metal must be removed from some part such as a forging, a modern sawing machine may be used to advantage on certain classes of work. The machining operation illustrated in Fig. 3 is typical. The parts are airplane wing terminals. A hydraulic sawing machine is used for cutting out stock from the solid square end to form a fork. Two saw blades are provided on the machine, so that the block of material to be cut out is removed in one downward feed of the saw frame. The saw blades are 1 1/4 inches apart. Two wing terminals are sawed at one time.

Fig. 3. Two Saw Blades Simultaneously Cut out Blocks of Stock from the Solid Ends of Two Wing Terminals

The wing terminals are located by slipping an arbor through the previously drilled hole in the square end and through bushings on opposite sides of the fixture. Guide blocks in the center of the fixture steady the blades as they move back and forth through the wing terminals. They cut down to the hole through which the arbor was passed.

Angular Cutting.—Most cutting-off operations are squarely across the bar or other part but angular cuts are sometimes required. With the hydraulically operated cutting machine shown in Fig. 4 cuts can be taken at right angles

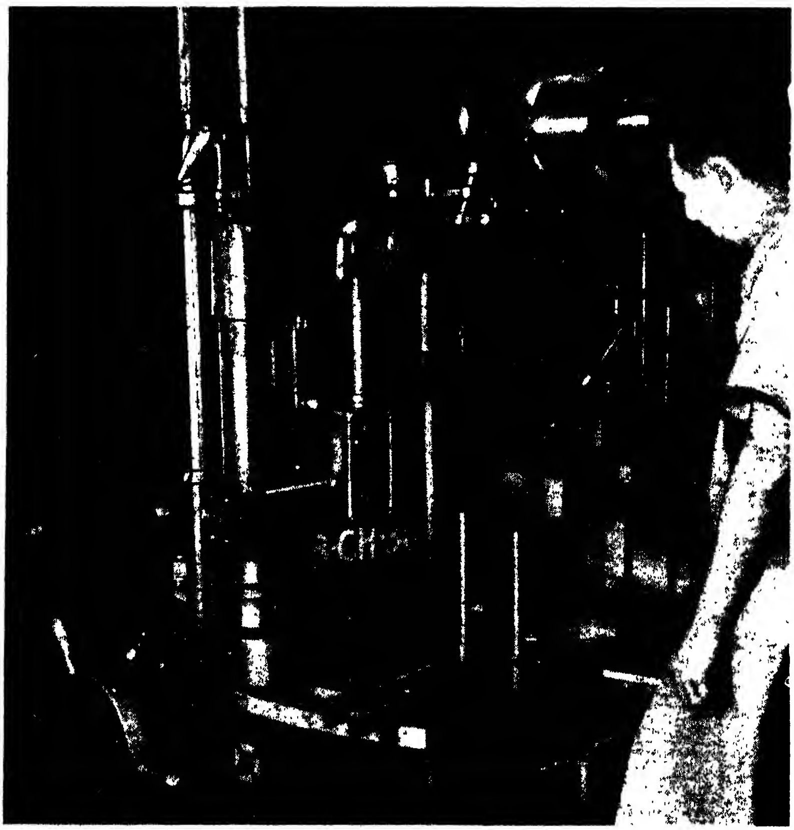

Fig. 4. Hydraulic Cutting-off Machine tnat can be Set for Making the Cuts Straight across or at Any Angle up to 45 Degrees

to the work in the usual manner or the saw frame can be swung around its column at the back of the machine to enable angular cuts up to 45 degrees to be taken across the work. In the operation shown, a test piece of armor plate is being cut. Steel billets up to 18 inches square or any number of bars having a total cross-section within that area come within the capacity of this machine.

The universal tool-room sawing machine illustrated in Fig. 5 finds wide application in cutting bars, tubes, etc., either straight through cross-sectionally or at any desired angle up to 45 degrees. In the illustration, the saw frame

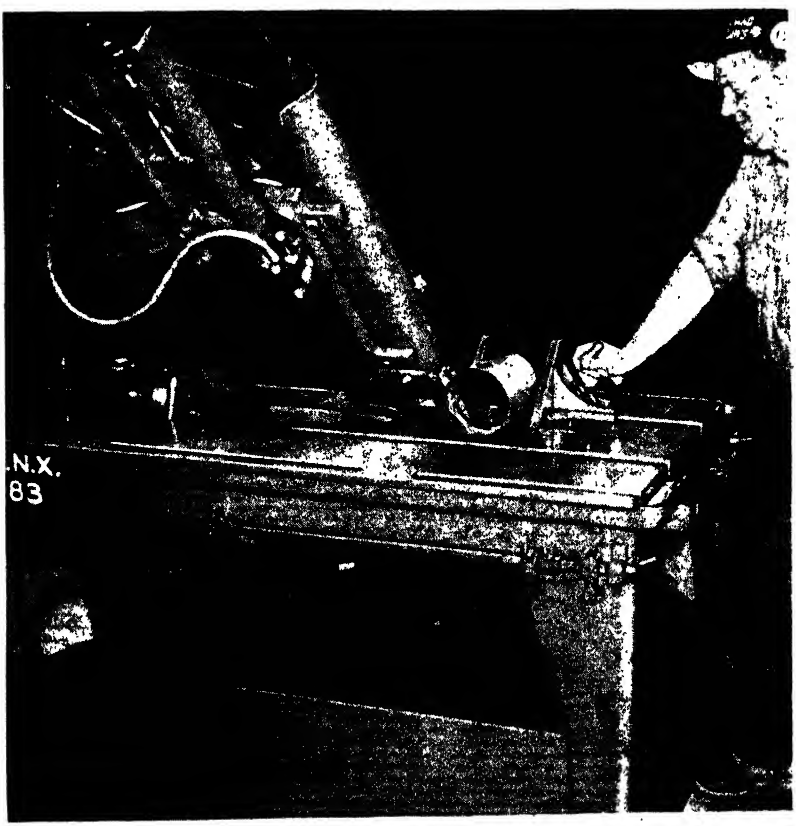

Fig. 5. Using a Sawing Machine of Band-saw Design for Cutting a Piece of Steel Pipe at an Angle

is shown tilted for taking an angular cut on a piece of steel pipe. The machine will accommodate one or more pieces of stock up to 12 by 12 inches in cross-section.

Band-saw Type of Machine.—The band type of sawing, filing, and polishing machines is used extensively for cutting small irregular-shaped pieces from steel plate. In Fig. 6 one of these machines is being used in the toolroom of an airplane factory for cutting out a two-inch-thick piece of duralumin plate for a wing tip die, to irregularly scribed outlines. An internal outline is being sawed after the part had been cut to its external shape. The table is tilted at an angle to obtain a slightly tapered cut. In order to start the internal cut, the operator first broke the saw band so as to enable passing it through a hole that was

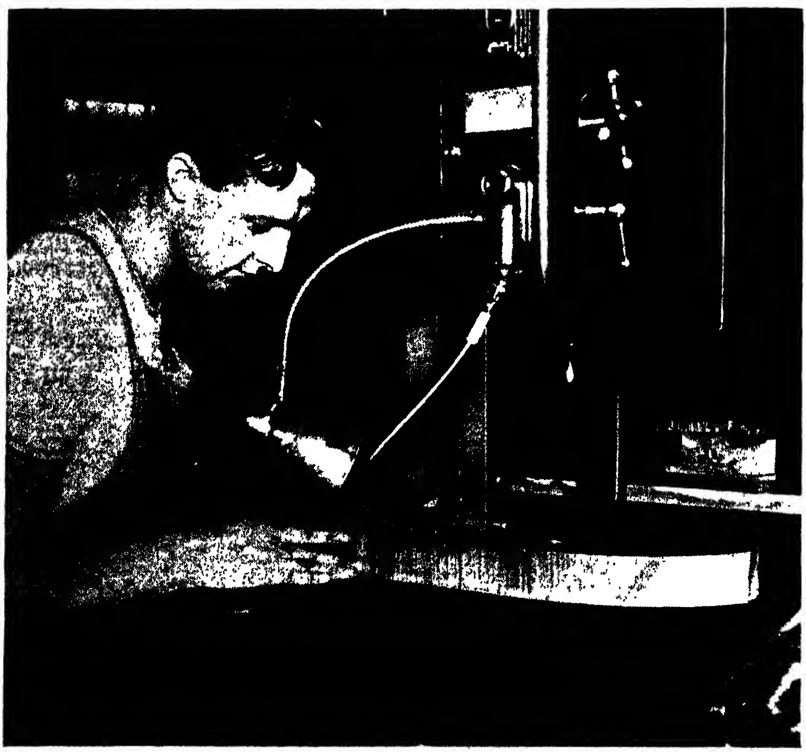

Fig. 6. Tool-room Operation on a Sawing, Filing and Polishing Machine

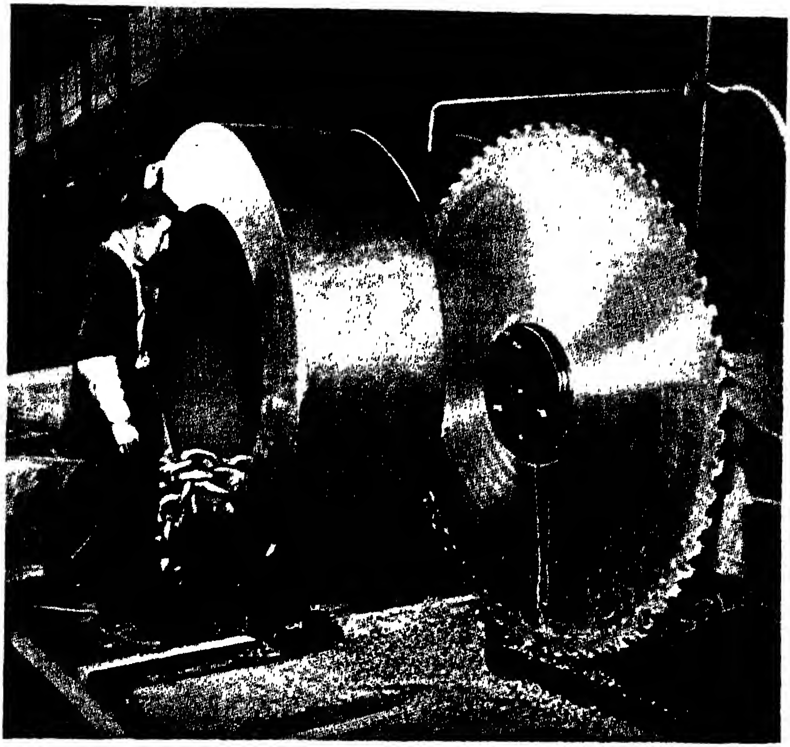

Fig. 7. Example Illustrating Unusual Application of Heavy-duty Metal Sawing Machine

previously drilled in the duralumin plate. He then rewelded the saw band by means of an attachment supplied on the machine.

Machines Equipped with Circular Type of Saw.—Cold-saw cutting-off machines which utilize a revolving saw are built in many different designs that differ principally in regard to the methods of driving the saw and giving it a feeding movement relative to the work. The saw is usually mounted on an arbor, which is rotated either through spur gearing, worm gearing, a combination of spur and worm gearing, or by the direct action of a sprocket engaging either the saw teeth or radial slots formed in the saw. A general method of feeding the saw is by means of a carriage or saddle which carries the saw and its driving mech-

anism, and is moved along the bed by a feed-screw. Saws of this general type may be applied to a wide range of cutting-off operations as illustrated by the example, Fig. 7.

Some machines are so arranged that the saw is given a swinging movement for feeding it, by mounting the saw upon an arm which is pivoted and connected with suitable feeding mechanism, which may be in the form of worm gearing, a pinion meshing with a segment gear on the arm, or a gear-driven screw connected with the arm.

The duplex type of cold saw consists of two machines mounted upon the same bed so that the distance between the saws may be varied. Machines of this type are used for cutting off the ends of axles, crankshafts, etc., to given lengths, and also for sawing crankshafts in order to form the crank or web from a solid forging. The multiple cold saw cutting-off machine is used for cutting long bars into a number of short lengths.

Some cutting-off machines have a vertical spindle and a saw which revolves in a horizontal plane. One design which is especially adapted for cutting off gates and risers from cast-steel gears, and other similar work, has a circular work table which is arranged very much like the table of an ordinary slotting machine. Another type of cold saw which is designed along vertical lines has a vertical column on the face of which is a saddle carrying a horizontal saw arbor, the saw in this case being in a vertical plane. The vertical column may be fed horizontally along the main base of the machine and the saddle may also be given a vertical feeding movement on the face of the column. A machine of this type is especially adapted for sawing armor plate.

Cutting Extruded Bars.—The cutting of extruded aluminum alloy shapes to required lengths has been facilitated in one plant by the installation of sawing equipment in back of long benches adjacent to the material storage department. In Fig. 8, a sawing machine is being used to cut tail-wheel fittings from extruded stock. The saw is moved back and forth on an over-arm to sever the stock by manipulating a lever at the front end of the over-arm.

This machine has an anti-friction mounted carriage, riding inside the arm which supports the motor. The saw is directly attached to the motor shaft. A foot-operated vise may be employed to hold the material. A detachable chain feed gives the operator an increased leverage, which enables him to feed the saw steadily into the material.

Trimming the Open Ends of Cartridge Cases. — In one munitions plant, the finish-drawn cartridge cases are transferred to the trimming machine in Fig. 9, which is equipped with a magazine for automatically feeding the

Fig. 8. Cutting Extruded Aluminum Alloy Shapes by Employing an Over-arm Type of Sawing Machine

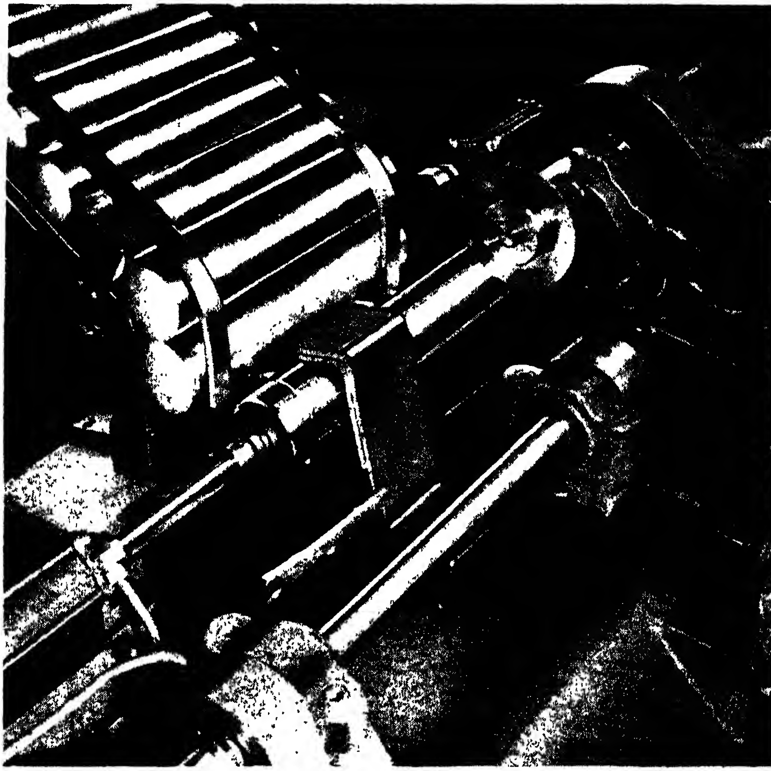

Fig. 9. An Automatic Machine Designed for Trimming the Open Ends of the Cartridge Cases

cases to the working position. A cam-operated slide at the bottom of the magazine pushes successive cartridge cases forward into line with an arbor attached to the headstock spindle. Then an air-operated ram on the left-hand end of the machine, as viewed in the illustration, advances to push the open end of the cartridge case on the headstock arbor.

A circular cutter, 6 inches in diameter, with the edge ground to about 45 degrees, next swings down on the cartridge case for trimming the open end to length. The arbor is fitted with a floating ring opposite the cutter. With the application of cutting pressure, this floating ring slides sidewise a limited amount, so as to permit the cutter to

shear readily through the metal. At the end of each operation, an air-operated rod in the center of the arbor and headstock spindle pushes the cartridge case from the arbor, and it rolls into the bed of the machine.

Cutting Plates with Rotary Type of Shear.—The rotary shear shown in Fig. 10 is applied for cutting plate to any desired curves, regular or irregular, as required in ship construction. The curves can be cut to radii as small as 4 inches and as large as required. Plates up to 1/2 inch

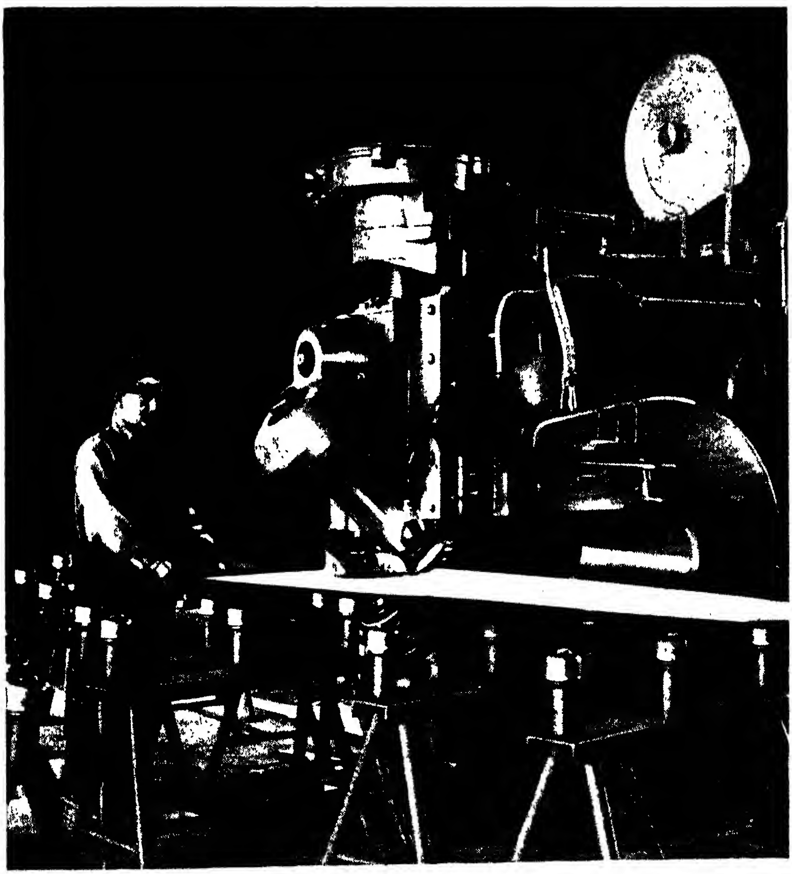

Fig. 10. Rotary Shears Employed for Cutting Steel Plates to Various Curves of Regular or Irregular Contour

thick are sheared straight through by this machine, and plates up to 5/8 inch thick are sheared by joggling them so as to feed a little at a time. In the illustration, the machine is shown set up for shearing with cutters 10 inches in diameter. These circular cutters are knurled to assist in pulling the plates along. Either right-angle or bevel cuts can be made.

Flame-cutting a Stack of Plates to Increase Output.— Quantity production of parts flame-cut from relatively thin steel plate by oxy-acetylene cutting machines is greatly facilitated by the use of a method that involves piling a number of plates one on top of the other, clamping them tightly together, and making the cut as if the clamped plates were one piece of solid metal. (See Fig. 11.) This process, known as "stack-cutting," has made possible the

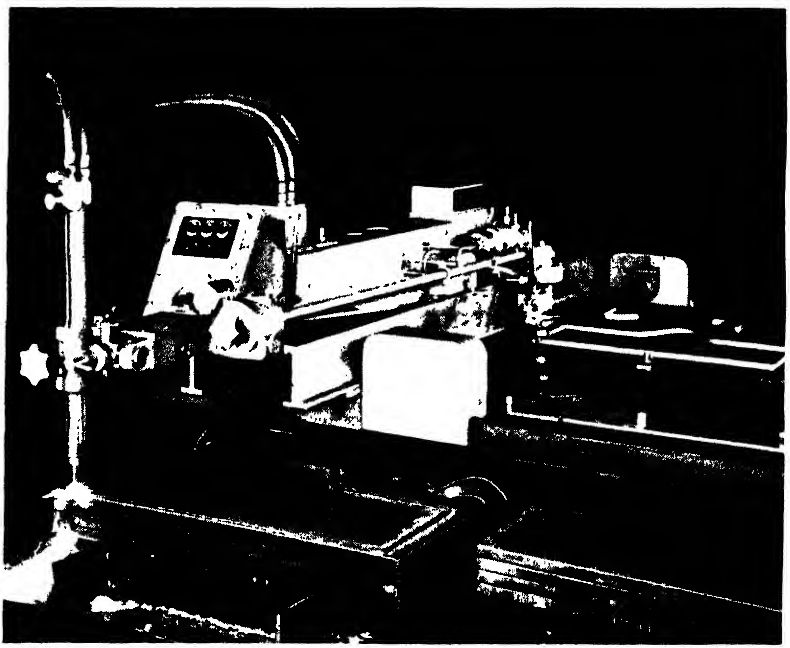

Fig. 11. Both Simple and Intricate Shapes are Produced by Oxy-Acetylene Machine-Cutting of Plates Stacked in Piles — Note Templet at Rear which Controls Path Followed by Cutting Torch

cutting of thin sheets and has resulted in an increase in the production capacity of the oxy-acetylene cutting machine, greater uniformity of the shape-cut parts, and a lowered unit cost of production. The following information is abstracted from an article by D. E. Roberts.

The success of stack-cutting is due to the fact that, when properly clamped together, several plates or sheets can be cut like one solid piece of steel. As in the flame-cutting of a single plate, the drive wheel of the cutting machine can be guided by hand or made to follow a templet automatically. Under proper operating conditions, the surface of the cut edges on all the stacked plates is left smooth and even, so that further machining is reduced to a minimum, and frequently eliminated, especially if the edges of the sheets are to be welded later.

In general, for plate of moderate thickness, it has been found that the best results are obtained on a stack of plates or sheets about 3 to 4 inches in thickness, although stacks of greater thicknesses can readily be cut. The accuracy of this type of cutting depends to some extent on the tightness with which the stack is clamped; with stacks thicker than 4 inches, the accuracy diminishes somewhat, due to the difficulty of obtaining a tight clamping.

On the other hand, a small stack is generally used when stack-cutting light-gage metal, so as to prevent burning of the top sheet with the large preheating flame which would be necessary for a thick stack, and also to prevent fusing of the sheets together by the greater heat.

Clamping Devices Used in Stack-cutting.—There are several methods of clamping in general use in stack-cutting. The choice depends upon the type of plate to be handled, the nature or shape of the cut, and the physical facilities at hand. The simplest type of clamp used in stack-cutting is the common C-clamp. (See Fig. 12.) Some of the other larger types are actuated by compressed air, hydraulic pressure, steam, or magnetic action. Bolting is preferred in some cases, while welding beads along the edges are used occasionally. Fig. 13 shows the application of quick-acting toggle clamps.

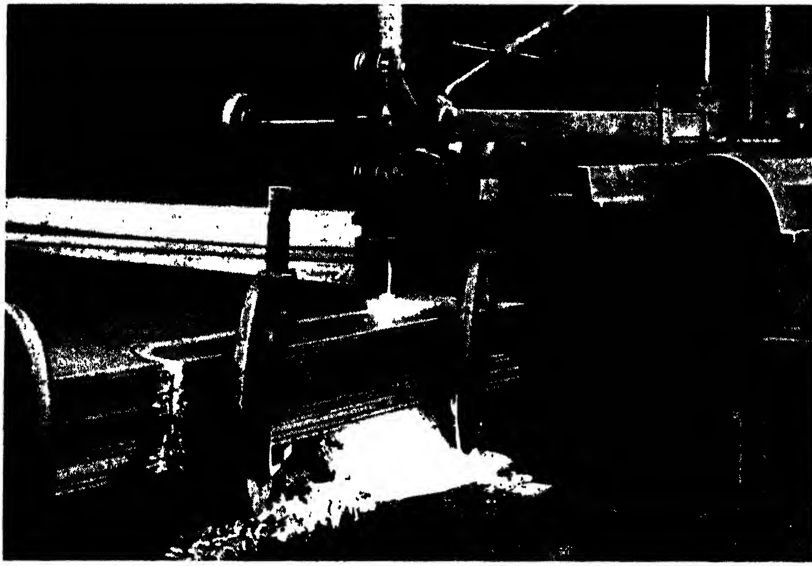

Fig. 12. Fifteen Plates, Each ¼ Inch Thick, are being Cut Simultaneously into Parts for Railroad Cars

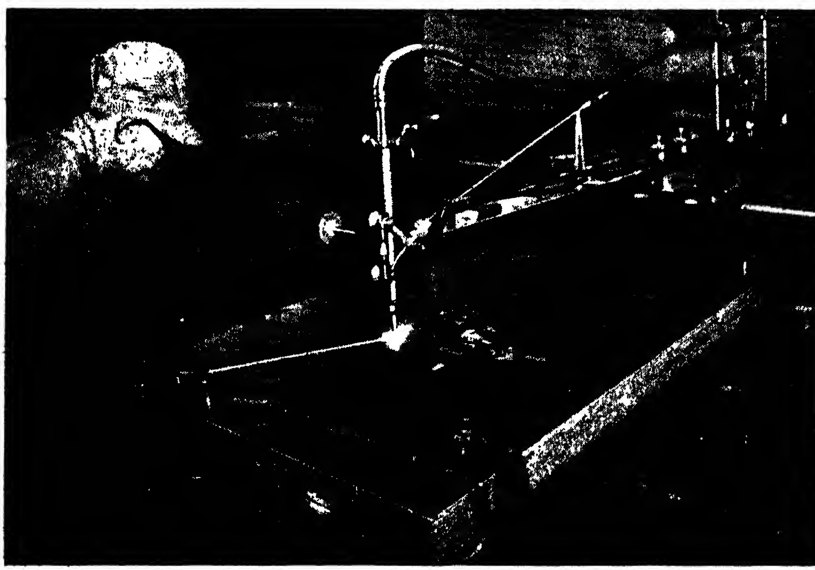

Fig. 13. Quick-acting Toggle Clamps Used to Hold Twelve ¼-inch Plates for Flame-cutting Coal-car Hopper Sheets

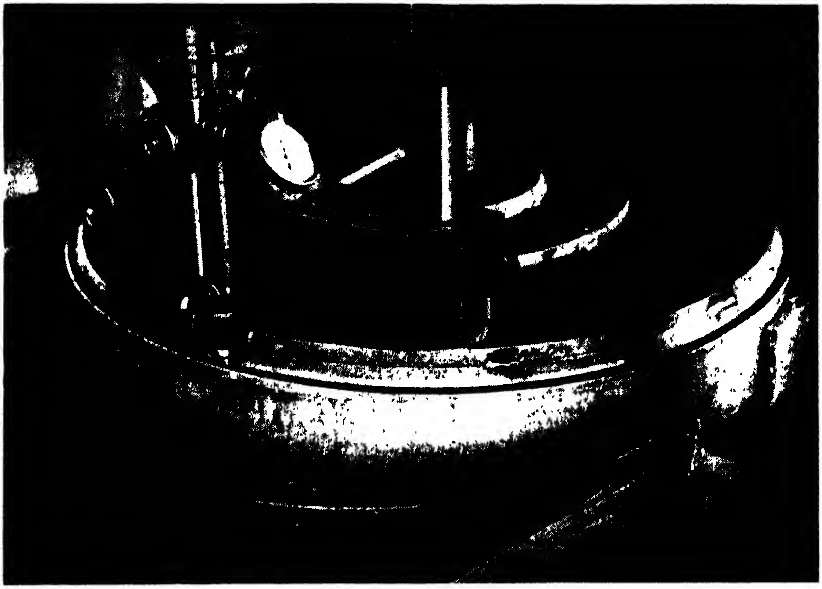

Fig. 14. Clamping Plate Applies Pressure to Stack while Cutting

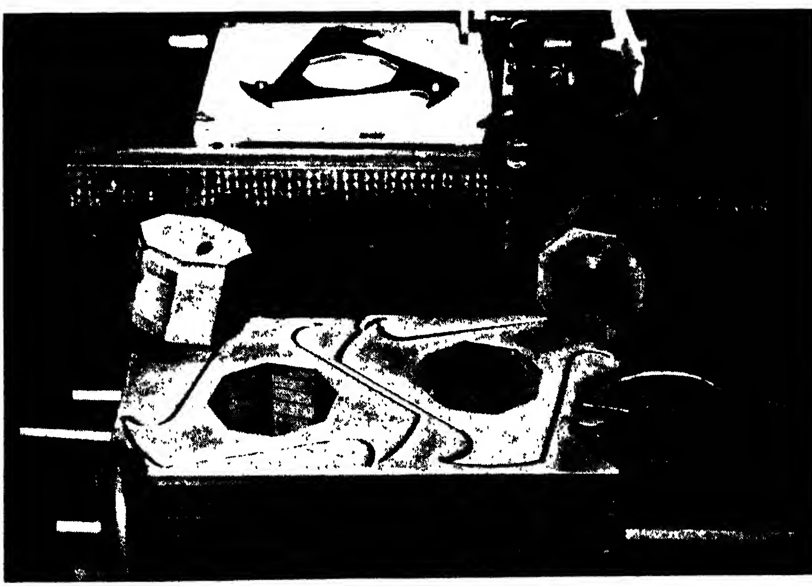

Fig. 15. Templet and Stack of Steel Plates with Two Parts Completely Cut Out

The combined heat from the preheating flames and the cutting action sometimes results in a slight adherence between the cut sheets. On thin sheets, some grinding may be required, especially where the cut is continuous. Where the sheets are eventually going to be welded, or where the steel composition is such that quenching will not produce objectionable hardness, it has been found that a jet of water playing on the kerf behind the blowpipe, or immediate quenching of the cut section in water, will cause thin sheets to separate immediately upon release of the clamps.

Plates of 10 gage or heavier will generally separate when subjected to impact, such as being dropped to the floor or struck with a hammer. If the parts cut out are fairly long, one end of the stack can be picked up and rested on an elevation of some sort. The arc thus formed will cause the sheets to separate so that a pinch bar can be inserted, and further wedging apart can be accomplished with a 2- by 4-inch timber, if necessary.

Stack-cutting Circular Disks.—In addition to the fabrication of large and heavy flame-cut steel parts for large-scale production or repair work, stack-cutting is now extensively used for cutting circular disks in plate varying from 1/16 to 1/2 inch in thickness, used largely for cylindrical tank ends. Stack-cutting provides one of the most economical methods of cutting such parts, and one that can easily and quickly be adapted to different sizes of disks from various thicknesses of plate. Cutting can be performed by means of stationary oxy-acetylene cutting machines or by small portable machines.

Circles of large diameter can be stack-cut on a production basis with a small portable cutting machine, as illustrated in Fig. 14. The job consists of cutting 39-inch diameter circles in 14-gage plate, fifty-four at a time, the stack being approximately 4 inches thick. The means used to clamp the plates consists of a heavy U-frame with a central screw jack. The jack works on a cover or clamping plate, which is first cut out approximately 1 inch less in diameter than the circles being cut. The cutting machine is automatically guided by a radius-rod, which is fastened to the

central screw jack by a movable collar and can be adjusted for cutting various diameters. The cutting of these fifty-four circles required 90 cubic feet of oxygen and an actual cutting time of about 15 minutes.

Stack-cutting Intricate Shapes.—Stack-cutting of small intricate shapes is readily accomplished by means of a cutting machine which can be made to follow a templet design automatically. The choice of clamping device will depend on the nature of the work to be done and the facilities avail-

Fig. 16. Oxy-acetylene Equipment Used for Cutting out Four Irregular Shaped Pieces Simultaneously. Note Master Templet and Magnetic Tracer at Right

able. For small pieces, toggle clamps are probably the most convenient, although the method of running welding beads up the side of the stack is very satisfactory.

A typical application of stack-cutting to the fabrication of small intricate shapes is illustrated in Fig. 15. A part called a German knife, used for cutting cloth in the manufacture of linoleum, was shape-cut by stack-cutting strips of 3/16-inch boiler plate, 11 inches wide and about 8 1/2 feet long. Six plates were cut at one time with an oxygen consumption of from 40 to 45 cubic feet per stack. The actual cutting time per stack varied from 9 to 12 minutes, which included making two starts, one for the octagon-shaped hole in the center of the knife, and the other for the outside profile.

Multiple Cutting on Machine Equipped with Magnetic Templet Tracer.—Pieces of plate may be cut to irregular outlines, as many as four at a time, by the type of machine shown in Fig. 16. This machine is provided, as shown, with a large table on which the work is placed at the left and templets at the right. Planograph arms move the oxy-acetylene cutting torches in the desired paths over the work as a magnetic tracer automatically follows the irregular contour of a cut-out steel templet. A manually operated tracer is also provided for use with scribed and drawn templets. The cutting torches are mounted on a square bar, about 12 feet long, on which they can be adjusted to the required center-to-center distances.

Punching and Riveting Sheets and Plates

When holes or other openings must be formed in flat sheets or plates, punches and dies are utilized for many classes of work. The punching of rivet holes is a common example. In fact, when holes are formed by punching, this is usually preparatory to riveting and machines have been developed which combine the punching and riveting operations. The use of a punching die for forming a hole or other opening is, of course, a very simple operation; but there have been important developments in means for locating either the work or the punches and dies, either to increase the efficiency of the operation or for reducing the initial cost of equipment suitable for a given class of work. Notable developments have also been made in riveting equipment. These points will be illustrated in examples to follow.

Application of Individual Punch and Die Units.—One application of individual punching die units is illustrated in Fig. 1. These individual units are designed for use in connection with any given layout. Each punch and die unit is located wherever a hole is required. The respective units may be held on a templet or baseplate which is made expressly for a given job; however, when the quantity of duplicate work is not large enough to warrant the making of a templet, a general-purpose baseplate containing closely spaced T-slots for receiving bolts, may be used instead. In using these T-slotted plates, the punch and die units are held on the plate by the bolts in whatever positions are required.

The multiple punching operation shown in Fig. 1 is performed on a press brake. For this particular operation,

the press is equipped with forty-four adjustable dies for piercing 3/32-inch diameter holes through airplane "skin." Each die is held in the bottom of a C-type holder and the punch in the upper arm of the holder. Coil springs normally keep the punch raised, so that the sheets to be punched can be readily slipped over the dies. When the ram descends, the springs are compressed so that the punches can be forced through the work. When the ram again moves upward, the springs withdraw the punches from the holes. The die-holders can be readily adjusted along the rail on which they are mounted to produce any required center-to-center distances between the punched holes. Some of the press brakes can accommodate twice as many dies as the machine shown.

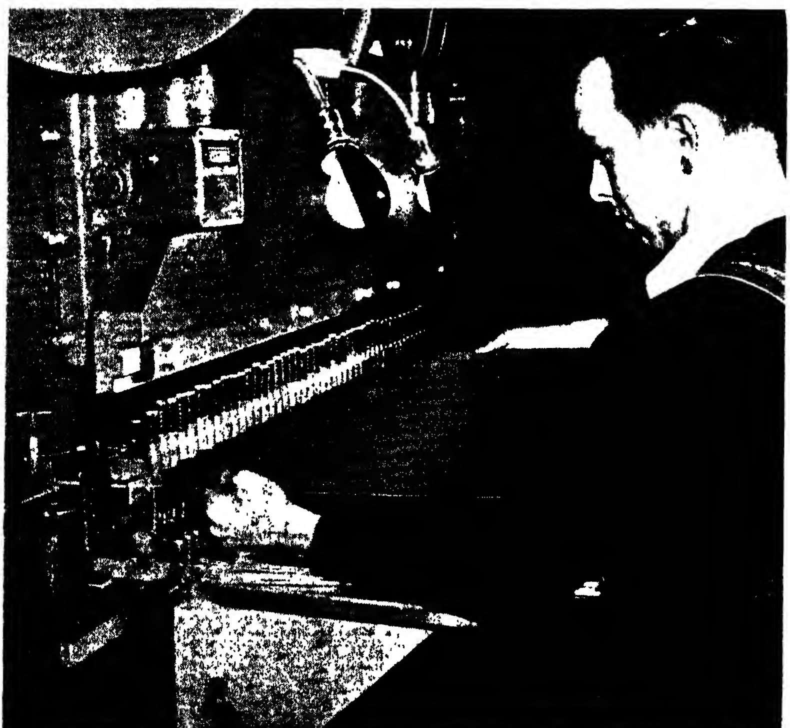

Fig. 1. Punching Forty-four Holes at One Time with Dies that can be Adjusted to Different Center Distances

The use of adjustable punches on a press brake for piercing a series of holes through the flanges of hat-shaped duralumin stringers is illustrated in Fig. 2. The punch-holders resemble C-clamps, and they are adjustably mounted along a rail in back of the long die member. When the ram of the press brake descends, it compresses the springs seen on the left-hand group of punch-holders and forces the punches through the work. The springs pull the punches back up when the ram rises again. The punch-holders seen at the right without punches and springs were not in use at the time the photograph was taken. In the operation shown, twenty-five holes were being pierced simultaneously.

Turret Principle Applied to Punching Operations.—When punches of various sizes, and possibly of different shapes as well, are required in producing a given part, the turret

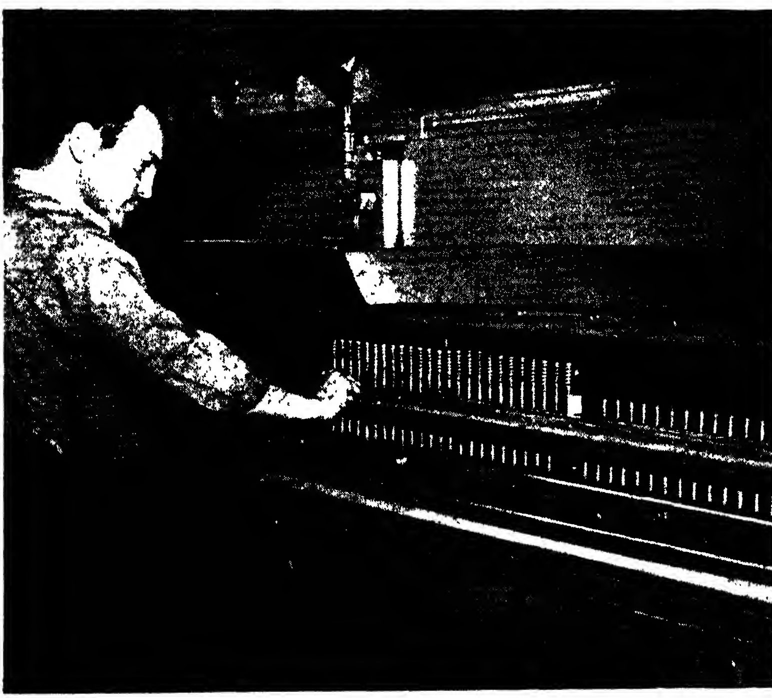

Fig. 2. Simultaneously Piercing Twenty-five Holes in Metal Shapes

principle has been utilized for locating each punch successively in the working position. This method is especially applicable to jobs which do not warrant the cost of a special die for punching all holes simultaneously, either because of the relatively small quantity of the work to be done or possibly because hole locations may make the construction of a die impracticable.

Fig. 3 shows one application of a turret type of punching machine. This machine is provided with both round and square punches to meet the varied demands of the sheet-metal shop. All together there are eighteen punches on the

Fig. 3. Turret Punching Machine with Eighteen Punches, Some Round and Others Square

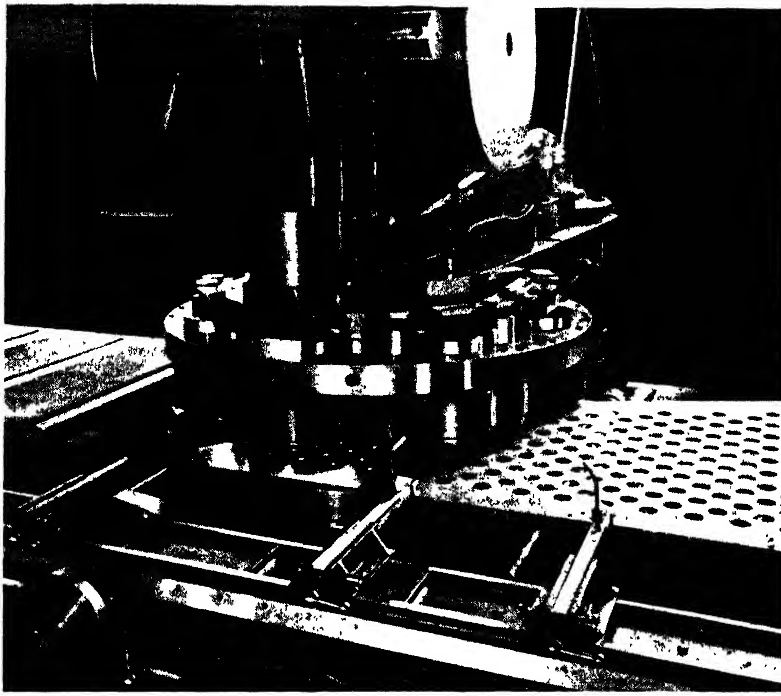

Fig. 4. Turret-head of a Punching Machine with Twenty-four Punches for the Rapid Cutting of Holes of Different Sizes in Aluminum and Sheet Steel

turret. The square punches range in size from 1 by 1 inch to 2 1/2 by 2 1/2 inches, and the round punches from 1 3/8 to 4 inches in diameter. Long slots can be cut by merely shifting the material sidewise by amounts slightly less than the width of the square punches between successive operations of the punching member. Guide bars at the back of the table, against which one end of the sheet is held, insure alignment of the holes.

The large turret-type punching machine shown in Fig. 4 has a throat of 54 inches and a punching capacity of 160,000 pounds. A close-up view of the turret-head of this machine is shown. With ordinary punches, this machine can blank holes up to 4 inches in diameter in 1/4-inch mild steel, and with shear punches, up to 6 inches in diameter.

Fig. 5. Punching Ship Plates on a Punching Machine Equipped with a Long Roller Locating Table

The turret is equipped with twenty-four punches ranging in diameter from 3/8 inch to 6 inches to suit the blanking of holes in platform plates and outriggers for anti-aircraft guns and other parts. Holes of the same size are punched all over the platform plate, but on outriggers the holes vary in size.

Any punch can be quickly indexed by power into the operating position. The turret is located in the various indexed positions by a plunger that enters bushings in the side of the turret. Tables on each side of the turret, fitted with rollers, and a long narrow table that extends across the front of the machine, are operated by power to position the sheets of aluminum or steel in and out or crosswise relative to the punch and die in operation. Scales on the front table and on the bed facilitate approximate settings, and graduated handwheels fine settings of the sheets to be punched. An indexing chart indicates successive turret and table settings on production jobs. This machine has greatly expedited operations previously performed by the use of templets.

Punching Machines with Roller Locating Table.—The fabricating shops of many shipbuilders are fitted with heavy punching machines of the type shown in Fig. 5 for producing the numerous rivet holes required in hull and bulkhead plates, etc. This machine is equipped with a long roller table, by means of which the steel plates can be quickly positioned beneath the punching tool in locations indicated by scribed lines and punch pricks. The entire table can be made to move in and out with respect to the punching tool by turning one of the large handwheels in the operator's station. By turning the other handwheel in this station, two sets of driven rollers near the middle of the table are actuated to move the steel plate longitudinally as required. The remaining sets of rollers are idlers, and revolve freely with the moving plate. At the front of the table are handwheels for raising or lowering the two rows of driven rollers in the center of the table. The over-all length of the table illustrated is approximately 100 feet.

Another punching machine for punching holes through

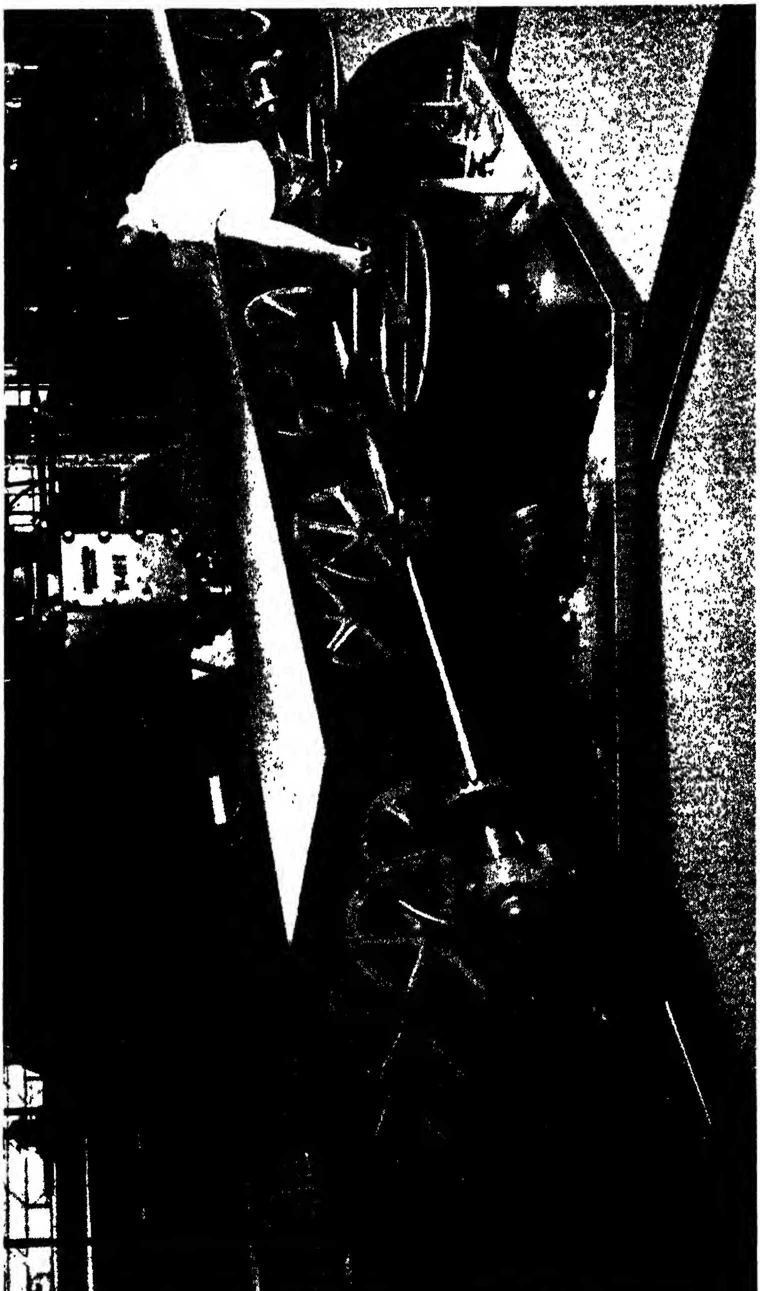

Fig. 6. Another Punching Machine Equipped with Long Roller Locating Table

steel ship plates is shown in Fig. 6. This machine is also equipped with a roller table by means of which the plates can be quickly positioned beneath the punching tool in accordance with punch-pricks previously laid out on the plate. Two sets of rollers on each side of the machine at the middle are actuated as the operator manipulates the lever held by his left hand to move the plates longitudinally. The remaining rollers to the right and left of the center are idlers and rotate freely as the plates are moved along. The entire table is moved in and out on four tracks as the operator manipulates a second lever with his right hand. Vertical adjustment of the driven rollers is accomplished through the large handwheels seen at the front of the table. This punching machine is employed on plates of mild steel up to 7/8 inch thick; the over-all length of the table is 50 feet.

Automatic Punching and Riveting Machine.—An entire volume might be written on the important developments in riveting equipment alone but since the space for each section must, of necessity, be limited, only a few examples can be given. These examples illustrate the more unusual types of riveting apparatus.

The automatic punching and riveting machine illustrated in Fig. 7 is employed for a wide variety of work that can be taken to the machine. This riveter is equipped with a swivel head for transferring the rivets from the lower end of a magazine into line with the ram of the machine after a hole has been punched through the two or more sheets of metal to receive the rivet.

The operator first depresses one of the foot-pedals, causing the ram to lower a hollow mandrel on the work and to operate a punch upward from the pedestal on which the work rests. The punch remains in the punched holes to hold them in accurate relation with each other while the operator depresses the second pedal, causing the swivel head to swing into its second position and locate a rivet above the punched holes. The ram of the machine then comes down, pushes the rivet through the holes in the sheets being assembled, and the punch out of the holes

ahead of it, the pressure of the punch causing the rivet head to be formed on the under side of the work. The illustration shows this machine being used in assembling a gasoline tank baffle.

Flush Riveting with Automatic Punching and Riveting Machine.— Flush rivets are employed in aircraft construction in order to reduce wind resistance to a minimum. In Fig. 8 is shown a close-up view of a beam type automatic punching and riveting machine which punches rivet holes through two or more sheets at a time, dimples the bottom sheet to accommodate the flush head, transfers the rivets from a magazine to the punched holes, and drives the flush rivet head.

The rivet holes are punched and dimpled by an air-operated ram that rises from beneath the sheets as an

Fig. 7. Air-operated Automatic Punching and Riveting Machine

upper ram descends to push a hollow-end tool on top of the sheets. This hollow-end tool is contained in the left-hand arm of a swivel head beneath the upper ram of the machine. The punching and dimpling operation is effected by depressing a button on a floor switch. After the holes have been produced, the punch remains in the holes to hold them in alignment until the rivet is driven. While the punching operation is taking place, the right-hand arm of the swivel head receives a rivet from the magazine.

When the operator depresses a second button on the floor switch, the right-hand arm of the swivel head swings into line with the upper ram, which then descends and pushes the rivet through the holes, the rivet being headed flush with the under side of the work by the resistance offered

Fig. 8. Automatic Machine that Punches Holes through Sheets, Dimples One Sheet, Inserts Rivets, and Drives the Flush Heads

by the receding punch. Both the upper and lower rams of the machine are air-operated.

Rivets with a flush head of 100 degrees included angle are used in this case. The magazine can be changed to suit the various sizes of rivets used, which range from 3/32 to 3/16 inch in diameter. Sheets of material being riveted together are supported on tables at the front and rear of the machine which are adjustable to suit the height of the work. The width between the housings of this riveting machine is 180 inches. At least twenty rivets can be driven per minute.

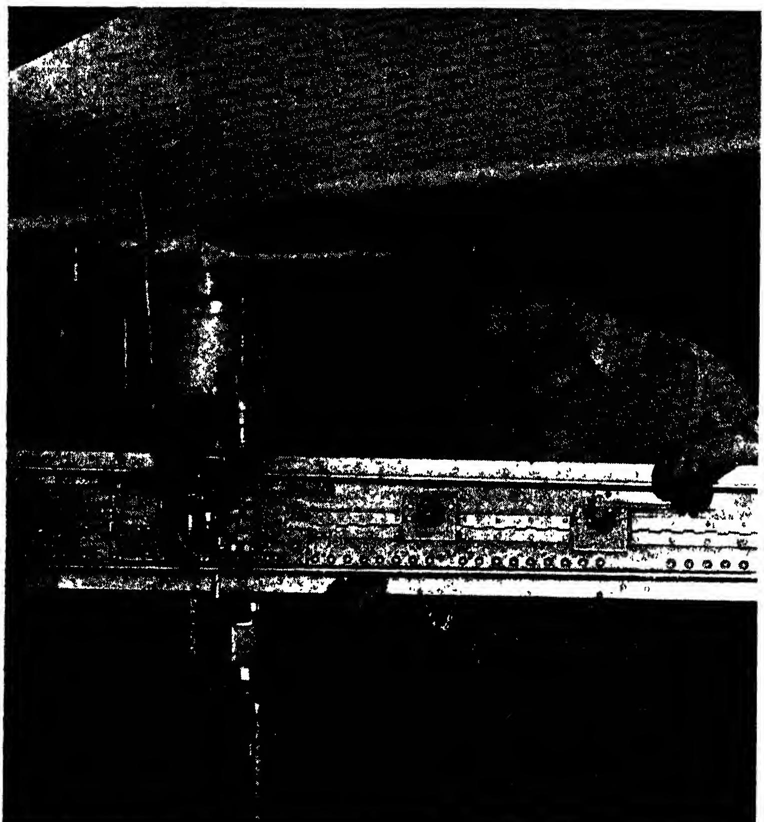

Fig. 9. Templets Secured to the Under Side of Parts to be Assembled Facilitate Automatic Punching and Riveting

Locating Holes by Means of Templet. — Automatic punching and riveting machines may be used in conjunction with templets which are attached to the work so that the operator can quickly determine the locations in which holes are to be punched and rivets headed. In the typical operation shown in Fig. 9, a templet is seen on the lower side of a long spar. In punching and riveting, the operator merely slips the templet from hole to hole over the nose of the stripper on the machine. This is done entirely by "feel," as the operator cannot see the templet holes, due to the fact that they are on the under side of the assembly.

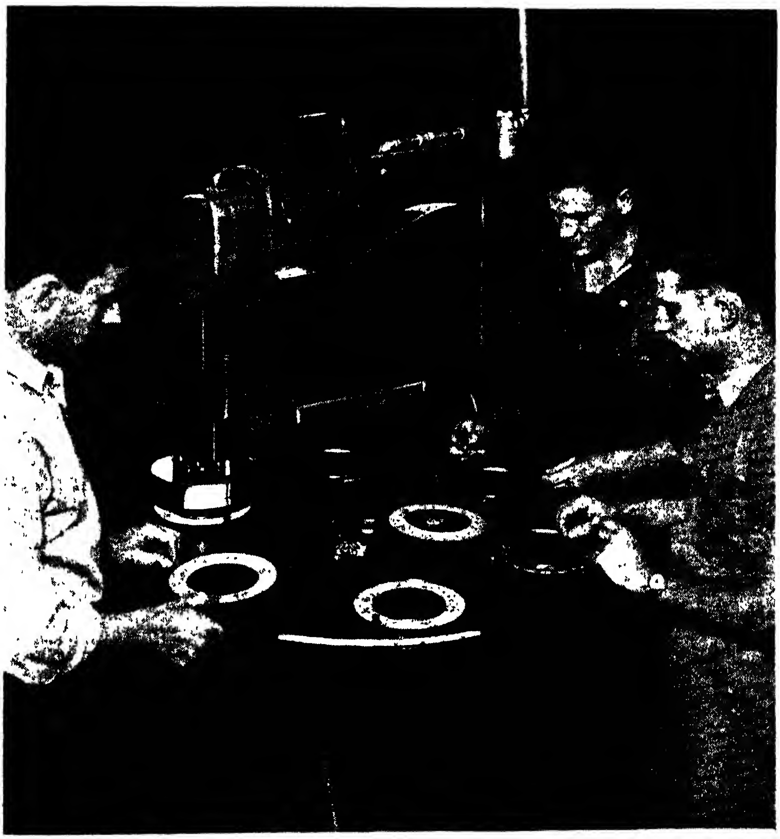

Fig. 10. Multiple Riveting Operation that Employs an Indexing Work-carrying Dial

Multiple Riveting on Machine Equipped with Work-carrying Dial.— A multiple riveting operation that has been speeded up by the use of a feed dial is illustrated in Fig. 10. This operation is performed on a special machine constructed with a pneumatic compression riveter which actuates a vertical slide to which a riveting head is attached. The operation consists of riveting together two flat rings and a retainer which holds a series of buttons. Eight rivet heads are squeezed at one time.

The two men seen at the right load the pieces to be assembled on spring-suspended disks in six stations of the

Fig. 11. Power Press Set-up for the Simultaneous Heading of Thirty-two Rivets; Auxiliary Die Plates are Reloaded while the Operation is in Progress

indexing table. Each station is automatically stopped beneath the heading slide, where the parts are gradually pushed down by the riveting head against the action of the springs that support the dial plates. The man at the left is kept busy removing the assembled units.

Punch Press Adapted to Multiple Riveting.— The adaptation of a punch press to multiple riveting is illustrated in Fig. 11. Sixteen stop-nuts are attached simultaneously to a sheet-metal cover by the heading of thirty-two rivets when the ram of the press descends. A helper sets up each cover with its stop-nuts and their rivets on auxiliary die

Fig. 12. Rivets are Squeezed Cold with This Portable 125-ton Riveter

plates which are slipped into position on a holder beneath the ram by the press operator, and withdrawn upon the completion of the riveting. They are then passed back to the helper for reloading. All the rivet holes are punched in the cover at one time by the use of another die before the covers come to the riveting operation, and immediately after the punching operation the holes are press-countersunk on one end to receive the flush-head rivets by means of a third die.

Riveting by Squeezing Cold Rivets.— Fig. 12 illustrates a riveting operation in assembling Army tanks. The nickel-steel rivets used are squeezed cold with the exception of those that must be driven in confined locations that are inaccessible to the large squeeze-type riveters. Rivets in such locations are driven hot by the use of small riveters of the pneumatic type. Along the sub-assembly lines the rivets are principally driven by huge stationary pneumatically operated machines which are installed with the anvil and ram positioned horizontally about 7 feet above the floor, thus allowing for the convenient handling of large plates. Along the final assembly lines the rivets are squeezed by the application of huge portable pneumatic squeeze riveters of the type shown in Fig. 12. These riveters are rated at a capacity of 125 tons.

Planing, Shaping, and Slotting Operations

The general application of machine tools of the planing or shaping type is so well known that few examples are included here, although such machines are indispensable in many lines of manufacture. One outstanding advantage of a planer type of machine tool is that it may be used for a large variety of work with a minimum of tool cost. This is due to the fact that inexpensive and easily forged, single-point tools are used ordinarily. This advantage applies to all machines in the planer family. There are three general classes of planing machines which are commonly known as planers, shapers, and slotters. Shapers are smaller machines than planers and are used for lighter work, whereas slotters, which might be considered as vertical planing machines, are used for operations that could not be done readily, if at all, on regular planers or shapers. These three classes of planing machines differ radically in their construction. Several different types of planers have been designed for planing certain general classes of work to the best advantage. There is, however, what might be called a *standard* design which is adapted to general planing operations. While the construction or design of planers of different makes varies somewhat, there are certain features which are common to all machines of the standard type.

While planers ordinarily do not require much auxiliary equipment, there are certain planer attachments which increase the range or capacity of the planer, and others which make it possible to plane special classes of work. Among

Fig. 1. Gang-planing Operation Requiring Six Tools

the planer attachments commonly used may be mentioned the extension tool-head which increases the planer capacity for handling exceptionally wide work, the floor stand or independent housing which still further increases the planer capacity, index centers for planing parts that require dividing or spacing, and various other attachments such as those for planing curved surfaces, spiral grooves, etc. These special attachments are needed more particularly in shops handling a wide variety of work.

Gang Planing Operation Requiring Six Tools.—In planing duplicate parts which are so shaped as to permit a planing tool to pass from one part to another, it is common practice to plane a row of parts in one operation. Moreover, when different surfaces must be planed, multiple tooling frequently is employed. An example of gang planing and multiple tooling is shown in Fig. 1. In this case, six tools are simultaneously employed for finishing the suspension brackets that support Army tank bogies. There is one tool on each side-head and two on each of the cross-rail heads. Twelve suspension brackets are mounted on the planer table at one time. Cuts are taken down vertical surfaces for a distance of about 12 inches by the tools on the cross-rail heads, while the tools on the side-heads machine a vertical surface for a height of about 16 inches and also a surface at right angles to the vertical surface on the overhanging shelf at the top of the brackets. Hardened and ground blocks mounted on supports near the left-hand end of the planer table serve as gages in setting the cutters into their approximate positions for taking the various cuts, feeler gages being used between the blocks and the tools. However, the actual tool positions as indicated by the cuts on the work are accurately checked by means of other gages. Cuts are taken in this operation to depths up to 1/2 inch. The castings are made of armor steel. All surfaces finished in this operation are checked by means of gages before the brackets are removed from the planer.

Open-side Planer Equipped with Special Tool-head.—The open-side type of planer has a massive column on one side of the table only so that the opposite side is open and

unobstructed, which greatly increases the range of the machine. The cross-rail or beam upon which the tool-heads are mounted is of very rigid design and has a broad bearing surface on the column to prevent deflection due to the thrust of the cut. The chief advantage of an open-side planer is that it can be used for machining large castings which would not pass between the housings of a two-housing

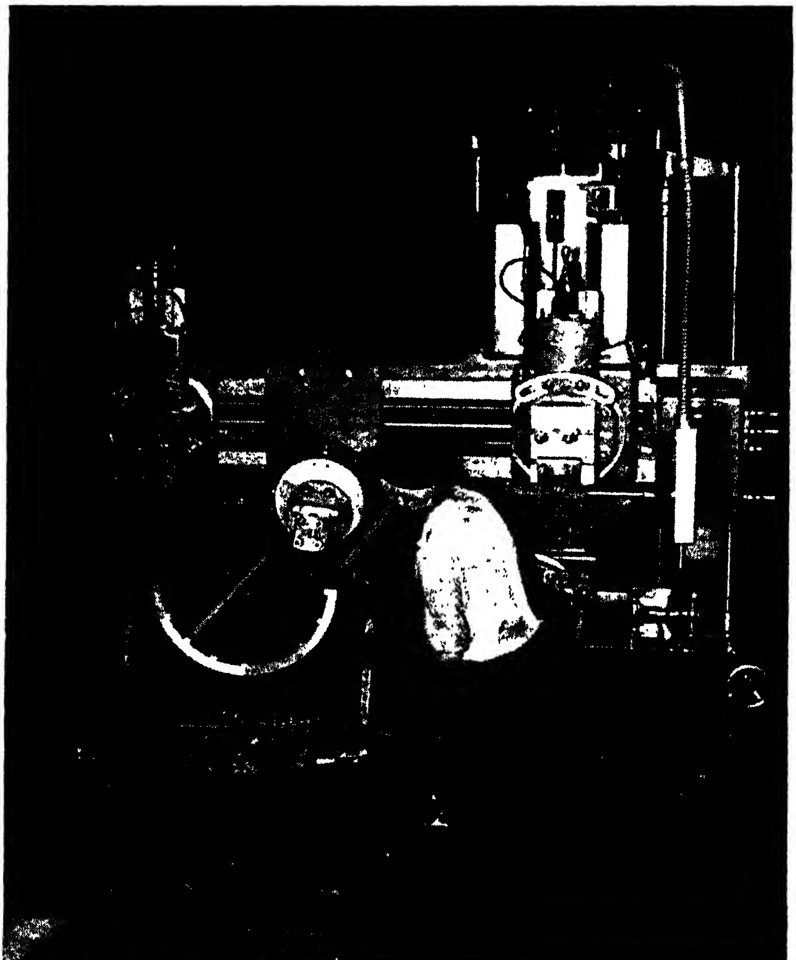

Fig. 2. Machining Grooves in a Stern Tube Bearing to Receive Rubber-coated Bronze Bars that Provide the Bearing Surface

planer of ordinary size. The driving and feeding mechanism of an open-side planer is similar to the regular type.

In Fig. 2 is shown an open-side hydraulic planer set up with a simple work fixture and a swiveling tool-head that facilitate the performance of a highly important operation on stern tube bushings for war vessels. The operation consists of finishing wide grooves around the inside of the bushings to receive rubber-coated bronze bars that extend the full length of the bushings and provide a bearing surface for the propeller shaft. At the time that the photograph was taken a cut was being made down the side of one of the lands. The bottom surfaces of these grooves are planed tangential or perpendicular to the radial center-line of each groove, after setting the tool-head at right-angles to the groove to be planed.

For this operation, the tool-head is positioned centrally with respect to the carefully lined up stern tube bushing. The special tool-head is provided with a slide for feeding the cutter tangentially across the grooves. Each groove must be located within a tolerance of 0.002 inch from the center of the bore. The width of the grooves is held within 0.001 inch. These dimensions are checked by means of "Go" and "Not Go" gages. The bushing is a bronze casting about 4 feet long. The cutting speeds on this planer can be adjusted from 0 to 50 feet a minute.

Duplex Radial Planing Attachment.—The planer illustrated in Fig. 3 is equipped with a special tool-head on the cross-rail by means of which two cutters can be simultaneously employed for milling opposite sides of a casting to a given radius. Each cutter is mounted in a circular holder which has worm-gear teeth around its periphery. In engagement with these worm-gears are two worms on a horizontal shaft, one right-hand and the other left-hand. After each return stroke of the planer table and before the next working stroke, the operator turns a small handwheel on the worm-shaft a slight amount so as to feed each cutter a small increment around the circular path that it is cutting. With this equipment, the rounded surfaces are planed simultaneously to the required radius within 0.005 inch.

Fig. 3. Planer Equipped with Radial Attachment having Two Cutters which Are Operated in Unison

Planing with Machines of Traveling Head Type.—The various steel plates that are used in constructing the hulls of ships and sections of armor plate must be machined along the edges, and in the case of some armor plating, keyways must be planed along these edges. Operations of this type are performed on plate planers, such as shown in Fig. 4. This particular machine shown has a length between the end housings of about 75 feet. In the operation illustrated, the edge of a comparatively thin plate is being trimmed, but the machine has been used on armor plate up to 12 inches thick. Cuts are taken by a cutter mounted on the carriage, which is fed lengthwise along the machine by a lead-screw approximately 9 inches in diameter. The work is held securely to the table of the machine by means of a series of overhead hydraulic jacks.

Thick armor plate is being machined for battleships

by the plate planer illustrated in Fig. 5. Cross-slides are provided on both sides of the carriage, which travels the length of the machine, so that roughing cuts can be taken as it feeds from right to left and also as it returns from left to right. In taking finishing cuts, however, a cut is taken in one direction only. Roughing cuts are taken to a depth of 1/8 inch and a width of 1 inch at a speed of 25 feet a minute. The work is clamped firmly to the table by

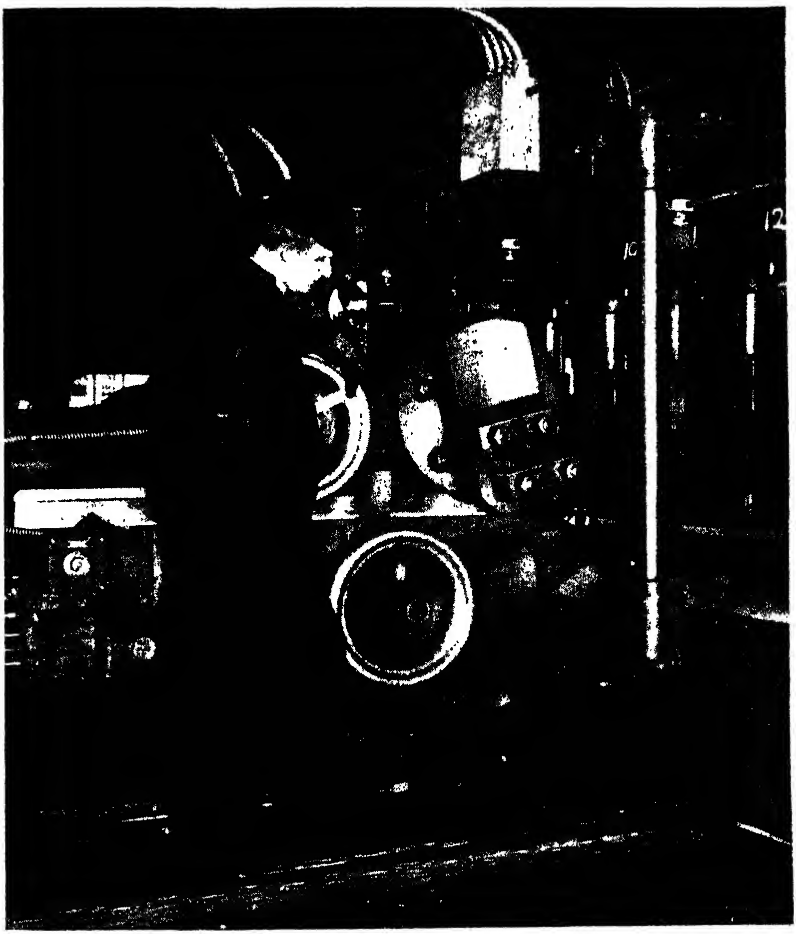

Fig. 4. Close-up View of Carriage on One of the Large Planers Used in Finishing Edges of Hull Plates and Armor-plate Sections

Fig. 5. The Double Carriage on a Plate Planer, Used in Machining One End of the Armor-plate Sections

means of twenty-four overhead pneumatic cylinders. This planer accommodates plate sections up to 46 feet long between the housings. A 6-inch lead-screw actuates the carriage. The tools used on this plate planer are of tungsten-cobalt tool steel.

Large Traveling Cross-rail Armor-plate Planer.—The large armor-plate planer, seen in Fig. 6, is designed with a stationary table and a movable cross-rail that is equipped on one side with two tool-heads for taking longitudinal cuts in both directions of the cross-rail movement over the table. On the back of the cross-rail is a third tool-head, which is fed crosswise of the rail for taking transverse cuts both ways across one end of the armor plates. The transverse cuts are taken with the cross-rail locked in one position on the two beds that extend along both sides of the table.

The cross-rail is 30 feet long, and the beds on which the cross-rail carriages ride are 60 feet long. Lead-screws 7 1/2 inches in diameter operate the carriages on which the cross-rail is mounted. These lead-screws revolve in a bath of circulated filtered oil. If for any reason the oil-pump that supplies the lead-screw troughs should fail to function, it would immediately become impossible to operate the planer.

The table of these planers is pivoted in the middle on a horizontal axis and can be tilted up and down to the required angles by the operation of four hydraulic jacks, two of which are provided at each end of the table. With this construction, the plates can be planed on one side to various angles with respect to the other side of the plates. This is merely done by machining one side to one angle for a specified length, then tilting the table to suit the angle of the next surface and proceeding as before. In this way, all angular surfaces on both sides of armor plates can be placed parallel with the path of the tool movements.

The practice is to plane the armor-plate sections on both the top and bottom of the two sides and ends to a width of approximately 4 inches, and also on the edges of the sides and the ends. All cuts are taken with one set-up of the work, which effects a tremendous saving in time over the

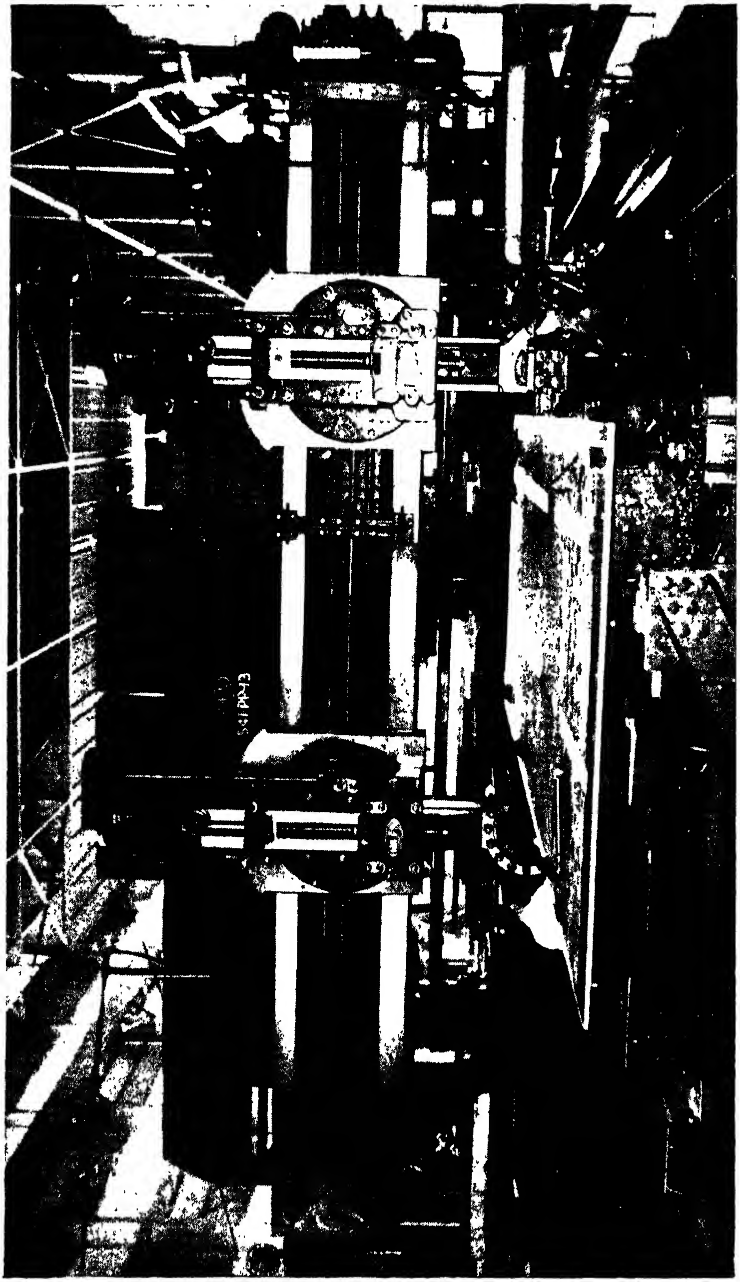

Fig. 6. Huge Armor-plate Planer Having a Stationary Table and a Moving Cross-rail Provided with Two Tool-heads for Longitudinal Planing and one Tool-head for Transverse Planing

previous method, in which the work had to be shifted each time that a surface was to be machined to a different angle. The tool-heads are generally controlled by operators riding on platforms attached to the ends of the cross-rail and to the transverse cutting tool-head.

The tool-heads used for longitudinal cuts are of a swiveling design, so that they can be tilted sideways to the required angles. In addition, the tool-blocks on the lower end of the rams can be tilted to facilitate various settings of the cutting tools. For operations in which it is necessary to feed the transverse cutting tool-head at an angle relative to the end of the table, the cross-rail can be adjusted to the required angle by locking one carriage to its bed and then traversing the opposite carriage along its bed until the desired setting has been obtained. This is accomplished by disconnecting either a coupling or a clutch in the drive from the main motor to the lead-screw of the cross-rail carriage that is to remain stationary.

Fig. 7 shows a view of the transverse tool-head cross-rail on the opposite side of this armor-plate planer. Motors on the ends of the cross-rail feed the tool-heads crosswise, as well as up and down. The cross-rail traverse screws are driven by a 150-H.P. motor at one end of the machine, which transmits power through clutches, couplings, and reduction gear units to the lead-screws of the cross-rail carriages.

Shaper Operation Requiring Indexing Fixture.—The shaper, like the planer, is used principally for producing flat or plane surfaces, but it is intended for smaller work than is ordinarily done on a planer. The shaper is preferable to the planer for work within its capacity, because it is less cumbersome to handle and quicker in its movement.

Fig. 8 shows how a shaper is used in a plant making anti-aircraft gun barrels, for cutting away the milled threads on the breech end, at three points around the barrel. This is done to obtain an interrupted thread that provides a means of quickly mounting and dismounting the breech ring when the gun is in service. The exact locations where the threads are to be cut away are determined from

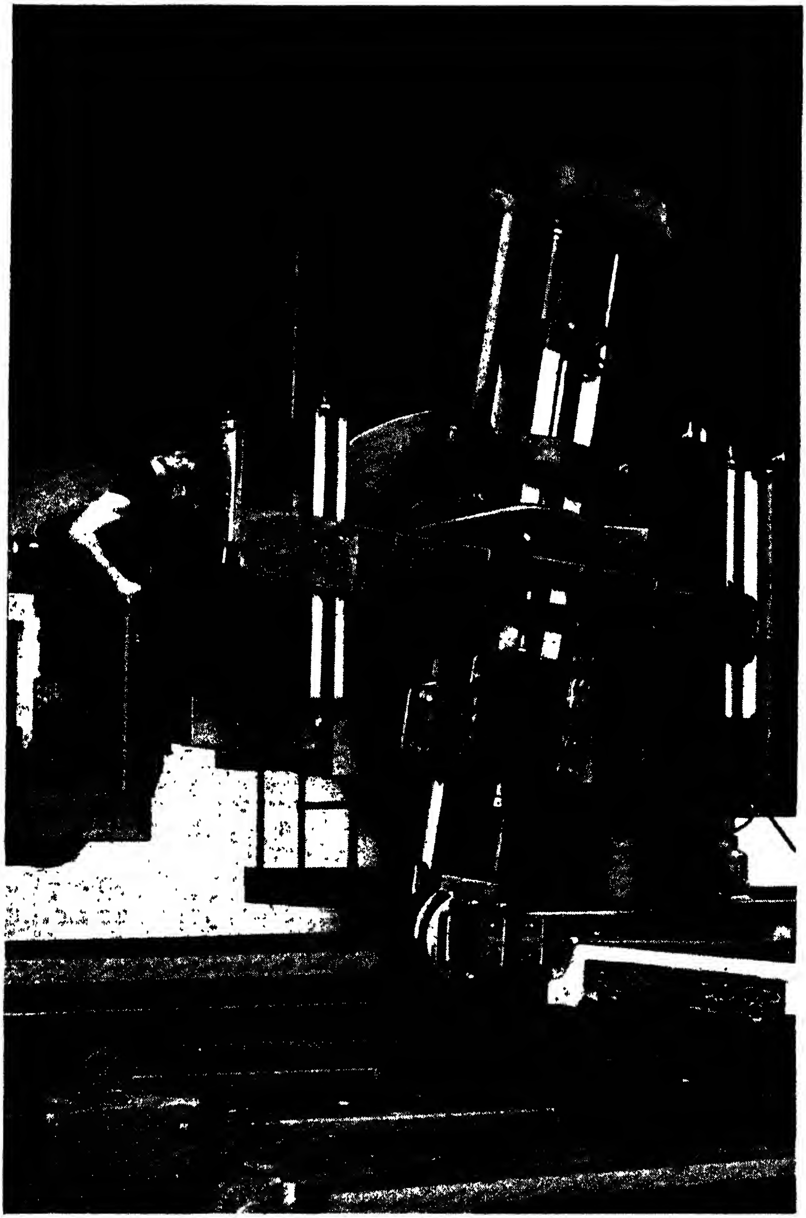

Fig. 7. Close-up View of Transverse Tool-head on an Armor-plate Planer which is Engaged in Taking a Cut across the End of an Armor-plate Section

a fixture mounted on the breech end of the barrel, as shown in the illustration. There are ground locating surfaces around this fixture from which the tools are set by the use of feeler gages. The shaper is equipped with a worm-operated indexing fixture to locate the various sections of the breech thread with respect to the shaper ram. A special bracket on the table supports the gun barrel about 3 feet in front of the table.

Planing Circular Surface with Vertical Shaper.—For some classes of work it is preferable to use a shaper of vertical design. The work-table of a vertical shaper can be given a transverse, longitudinal, or rotary movement. The ram which carries the planing or slotting tool moves verti-

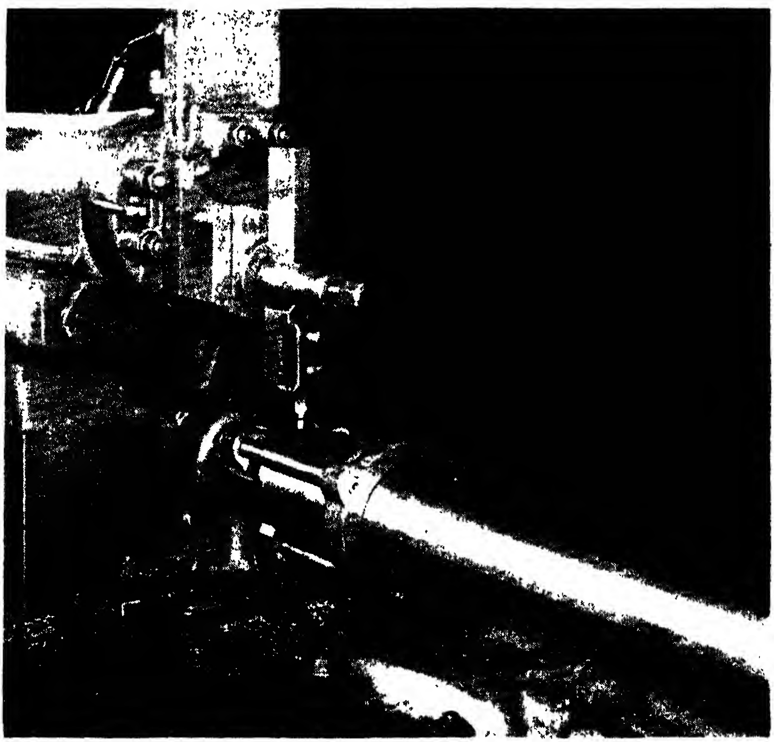

Fig. 8. Shaper Cutting away Portions of the Thread on the Breech End of Anti-aircraft Gun Barrel

cally, while the table is fed either by hand or automatically in whatever direction is required. The ram can be placed perpendicular to the table or at an angle for slotting dies, etc. It is mounted in an independent bearing, the upper part of which is pivoted, so that both the bearing and ram can be adjusted to an angular position, which is indicated by degree graduations. Work can often be completed at one setting by a shaper of this type, as it may be used for machining either straight, curved, or irregular surfaces. The vertical shaper shown in Fig. 9 is finishing the rounded contour of a fork end. The work is located on a simple fixture from one of the previously milled fork surfaces, and

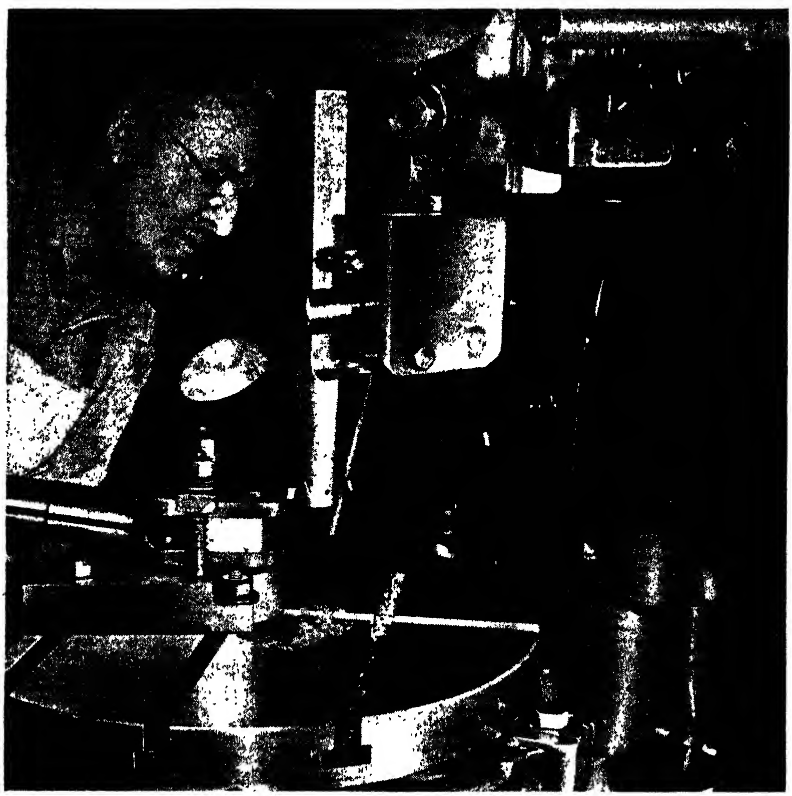

Fig. 9. Vertical Shaping Operation on Rounded Ends of Fork

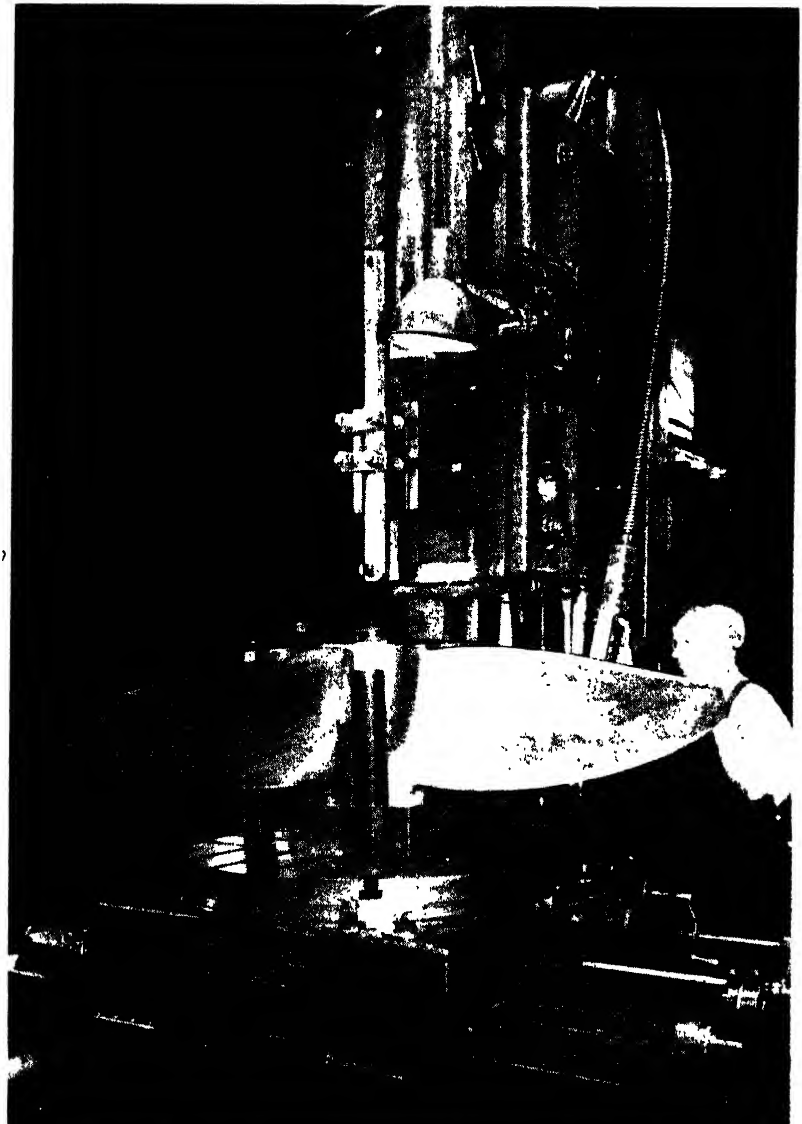

Fig. 10. Cutting Keyway in Tapered Bore of Propeller with Hydraulic Slotting Machine

the rotary table is power-fed to gradually carry the rounded end past the reciprocating tool at the required radius.

Cutting Keyway in Tapering Bore with Slotter.—Fig. 10 shows a hydraulic slotter being used for cutting a keyway in a propeller for a small patrol boat. The machine is especially adapted to this type of work because the tool ram can be tilted forward to suit the taper bore in the propeller, whereas the set-up presented some difficulty when such an operation had to be performed with the equipment previously available. Cutting speeds from 0 to 80 feet a minute are obtainable with this machine, and return speeds from 0 to 150 feet a minute.

Milling with Machines of Horizontal-Spindle Type

In machinery manufacturing plants of practically all types, milling machines are used extensively for a wide variety of operations. The milling process represents a practical application of the rotary principle whereby a succession of cutting teeth comes into action with each cutter rotation so that during the cutting period the action is continuous. The process is adapted both to the forming of plane surfaces and the milling of irregular forms either by using a cutter of special shape or by mounting, upon an arbor, a gang of standard cutters whenever this is feasible.

The milling operations illustrated in this section are performed on machines having horizontal spindles. Some machines with horizontal spindles are classed by the manufacturers as *plain* machines to distinguish them from the *universal* type which also has a horizontal spindle but is capable of certain adjustments and may also be equipped with attachments adapting it to a comparatively wide range of work. Some horizontal spindle machines are known as the horizontal type, and various other names are used.

On all of these milling machines having horizontal spindles, the cutter, or gang of cutters, is usually held on an arbor driven by the spindle, although in some cases a face-mill or end-mill is held and driven directly by a spindle. The examples which follow are intended merely to illustrate, in a general way, the wide application of these machines. The variety of milling operations is practically endless.

Milling with Two Groups of Cutters.— Fig. 1 shows a milling machine with a hydraulic table feed, which is used for milling a slot for the shutter slide across the end of a percussion fuse magazine. This slot is cut almost the complete width of a boss on the closed end of the part, only a narrow wall being left on the opposite sides of the slot. The depth of the slot is of utmost importance, because the thickness between the bottom of the slot and the chamber in the opposite side of the piece must be held within 0.025 to 0.030 inch. Later a fine cut is taken on a drilling machine to reduce the thickness of this "diaphragm" to between 0.008 and 0.012 inch. At the front of the milling machine may be seen two of the magazines before and after the slot milling operation.

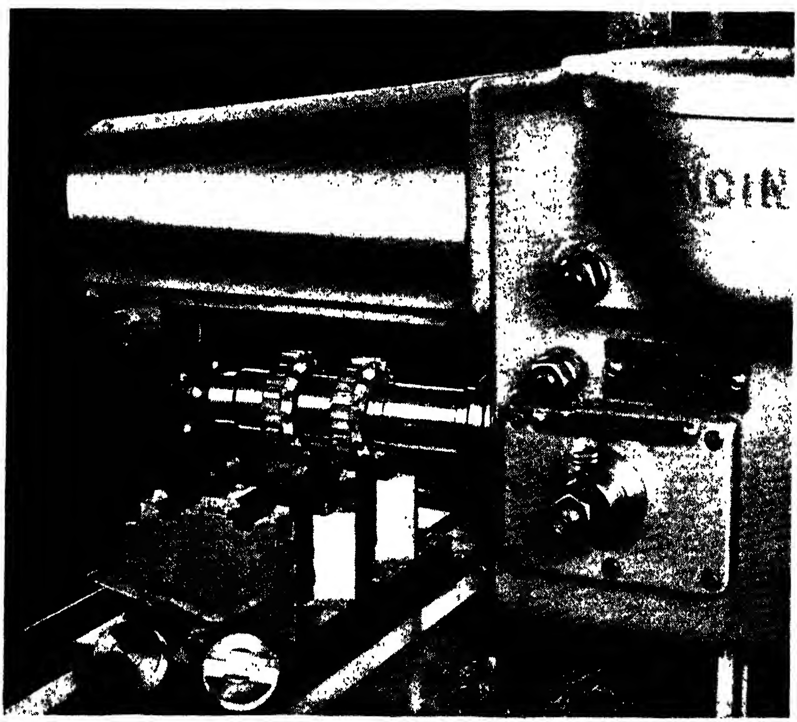

Fig. 1. Milling and Chamfering a Slot in a Percussion Fuse Magazine

The parts are loaded four at a time in the fixture of the milling machine, with the side in which the slot is to be cut held at two points against locating surfaces on a top member of the fixture. The pieces are slipped sidewise into the fixture under this top member, and are then raised into contact with the locating surface by handles at one end of the fixture, which operate eccentrics beneath the blocks on which the parts rest. Six cutters are mounted on the arbor of the machine for cutting a groove in the four work-pieces with one table movement. The cutters are arranged in two groups, each consisting of a plain milling cutter in the center which machines the groove to its full width and depth, and an angular cutter on each side for beveling the top edges of the groove.

Machine Provided with Duplicate Work-holding Fixtures.—The sides of four articulated airplane engine rods are slab-milled simultaneously on a milling machine set up as shown in Fig. 2. The four rods are assembled on two arbors which pass through the bores at both ends. One of these arbors is ground square on the ends to provide flat surfaces for accurate locating and clamping purposes, while the other arbor is ground three-sided on the ends for the same purpose. Two fixtures and two sets of cutters enable a group of four articulated rods to be loaded while another group is being milled.

Milling Hexagonal Sides and Cutting Castellated Slots.—Special nuts are "hexed" and castellated on the milling machine illustrated in Fig. 3, which is equipped with a double indexing fixture that enables the operation to be performed on six nuts while a similar number are being loaded. This operation is performed after the nuts have been produced from bar stock in automatic screw machines and tapped. The nuts are held by being screwed on studs on the fixture.

There are nine cutters on the arbor of the machine. The fixture is fed past the cutters three times for milling the hexagonal sides with the wide-faced cutters, the fixture being indexed between each pass. Then it is shifted horizontally to bring the center of each nut into line with one

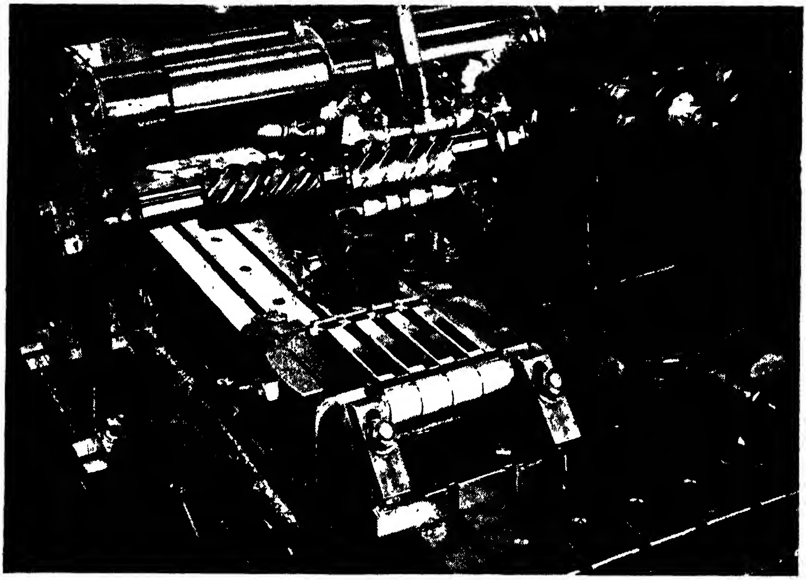

Fig. 2. Finishing the Sides of Airplane Engine Articulated Rods

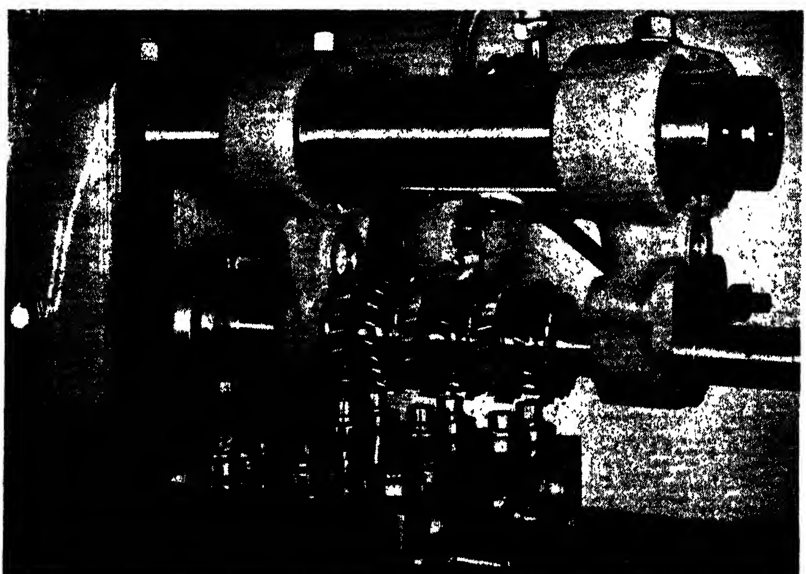

Fig. 3. Milling Sides of Hexagonal Nuts and Castellated Slots

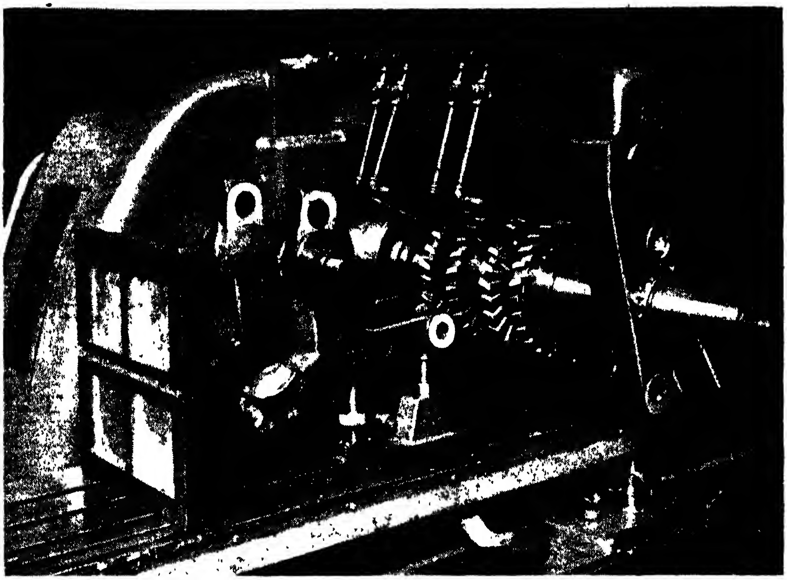

Fig. 4. Milling Operation on Inner and Outer Bracket Faces

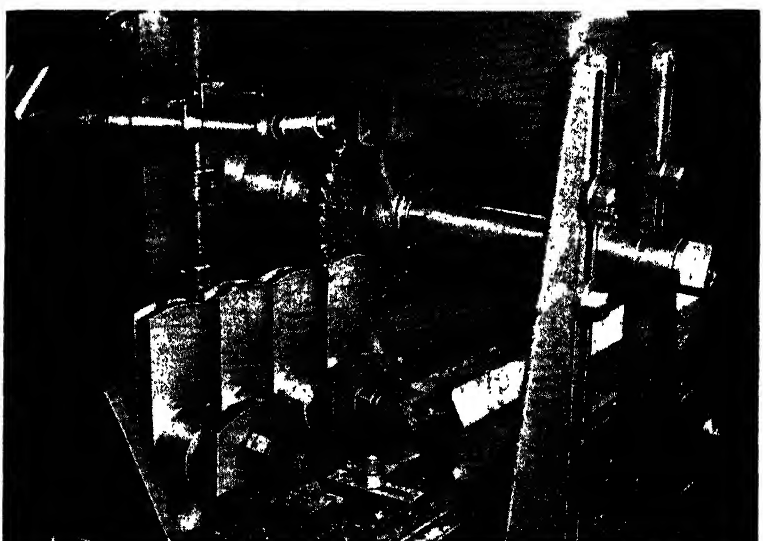

Fig. 5. Conventional and Climb-cut Milling are Both Utilized for this Operation

of the thin cutters, after which the nuts are again fed past the cutters three times, and indexed between each pass, for cutting the castellated slots.

Milling Inner and Outer Faces on Bracket.—A front bogie bracket is being milled on two inside and two outside boss faces by four inserted-blade cutters, 10 inches in diameter, in the operation illustrated in Fig. 4. The casting is held in a fixture of such a design that it can be used for three different operations on the same part. In these operations, the fixture is set up on two different faces. The machine table is reversed automatically when it comes in contact with a stop.

Conventional and Climb-cut Milling.—In milling, the feeding movement and cutting movement are in *opposite* directions, as a general rule. This is sometimes known as the "normal" or "conventional" method of milling to distinguish it from the climb-cut method. The term *climb-cut* or *climb* milling means that the feeding movement of the work and the cutting movement are in the same direction.

Both conventional and "climb" milling are performed by the machine illustrated in Fig. 5, engaged in finishing slotted arms on the rear ends of airplane-engine crankshafts. An area about 3 inches square is finished on one surface of each part as the table feeds from left to right, and on the opposite arm of each part as the table returns to the left. At the end of this operation, the width of the slot must be 0.807 inch within plus nothing, minus 0.005 inch, and the thickness of one arm must be to the specified dimension within plus or minus 0.002 inch. When these parts reach the milling machine, the arms are solid. They are first hobbed out and then finish-milled.

Application of "Rise-and-fall" Milling Machines.—"Rise-and-fall" milling machines are especially adapted for certain operations. In Fig. 6, a milling machine operating on this principle is seen engaged in an operation on the slide butt for a machine gun. As will be apparent from the part lying at the front of the table, it is necessary for the

cutter to be lowered for milling the surface that is seen finished, and raised at the end of the cut, in order to clear the lugs at the opposite ends of the pieces. When the operation is started, the spindle carrier is fed downward hydraulically at a rapid rate until it almost touches the work, and then fed at a slower rate to the actual cutting depth, which is controlled to within 0.0003 inch. The table is then fed horizontally, and just before the bosses on the right-hand end of the work are reached, the spindle carrier again moves upward. Right- and left-hand sides of the slide butts are milled. The table is also actuated hydraulically.

Fig. 6. Rise-and-fall Milling Machine Employed for an Operation in which the Cutters Must be Moved Vertically in Order to Clear Higher Surfaces at Both Ends of Work.

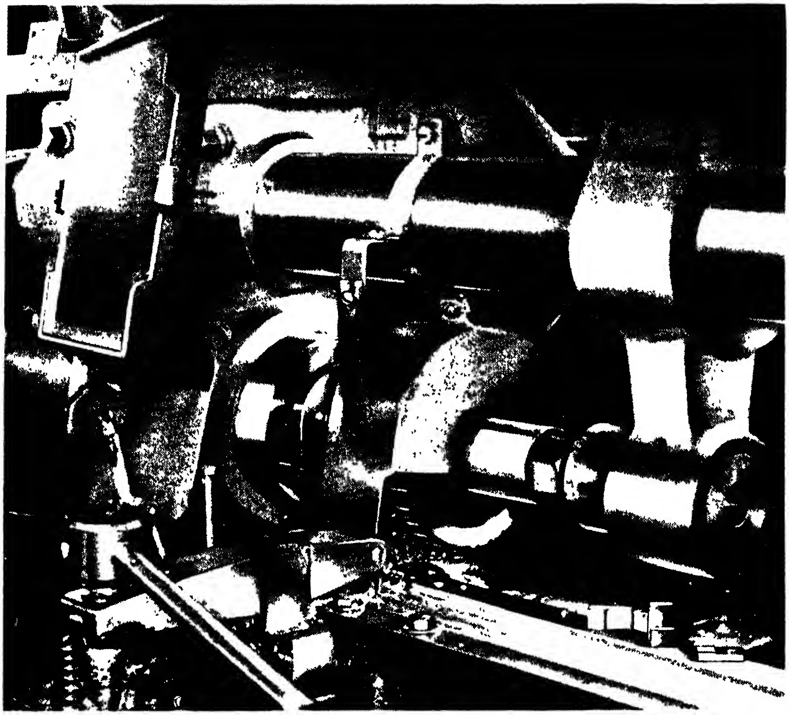

Fig. 7. Milling Machine Equipped for Milling and Cutting off Small Pieces from Rectangular Brass Stock

Milling and Cutting-off Operations Combined.—In Fig. 7 is shown a machine employed for slab-milling the top of light brass bars of rectangular cross-section, and cutting off the milled pieces in a second step to produce parts such as seen in the lower right-hand corner of the illustration. The bars are 1/4 by 3/4 inch in cross-section, and are fed to the cutters four at a time, being held between guides on a long table at right angles to the cutters. Two shoes on an equalizing clamp are brought firmly down on the pieces adjacent to the milling cutters by turning a handle.

When the work-pieces are fed to the cutters, the plain cutter seen at the right cuts a groove 3/4 inch wide to a depth of 1/16 inch across the four pieces. At the same time, a thin saw, about 3/8 inch to the left of this cutter,

cuts off the section of the bars milled in the preceding step. Thus, when an operation has once been started, four pieces are obtained with each traverse of the table past the cutters. At the end of the cut, the clamp is raised to release the bars of stock so that they can be advanced against the end stop, ready for the next operation.

Milling Cycle Automatically Controlled. — The milling operation shown in Fig. 8 is of unusual interest because of the automatic cycle of the machine. The machine is actuated hydraulically. It is used for milling two

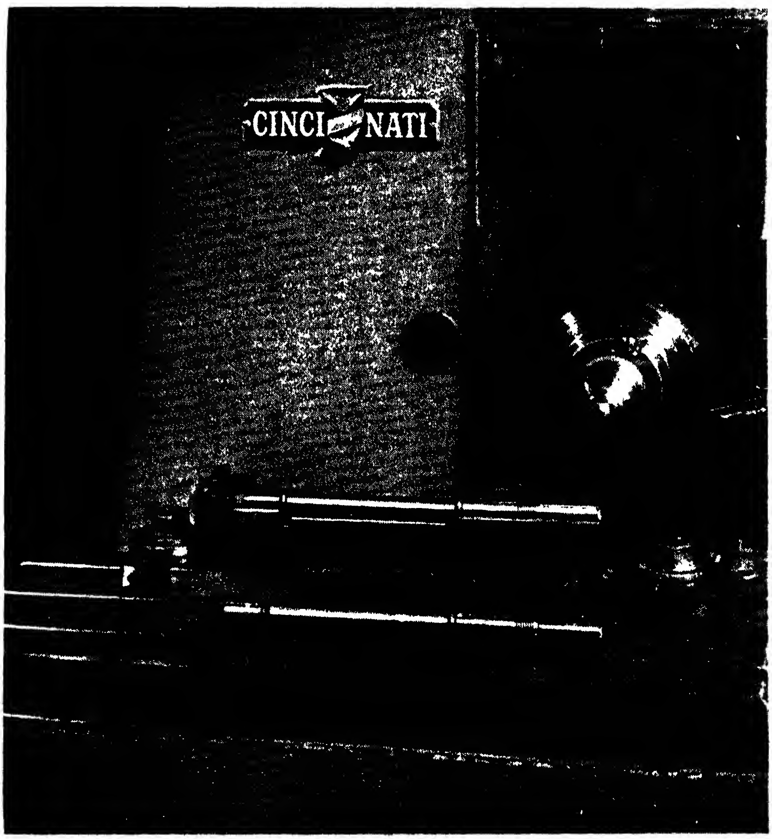

Fig. 8. Milling Two Woodruff Keyways in Gear-shafts

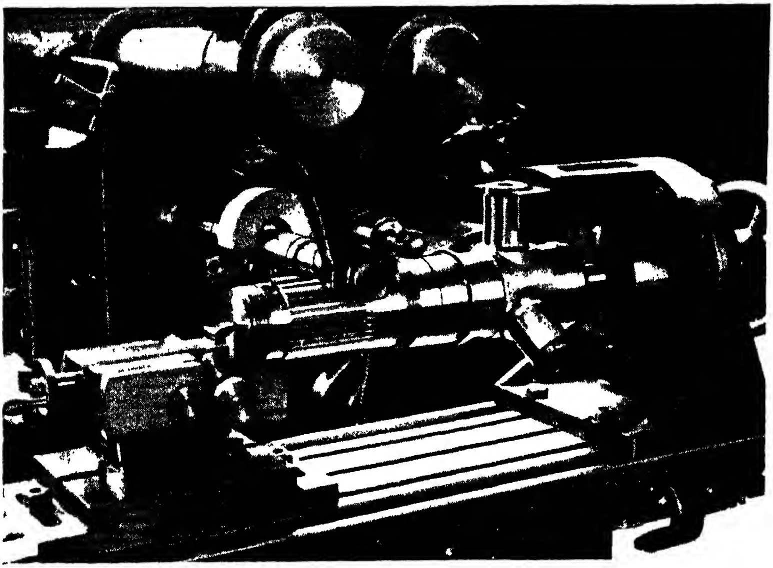

Fig. 9. Milling the Splines on an Airplane Propeller Shaft

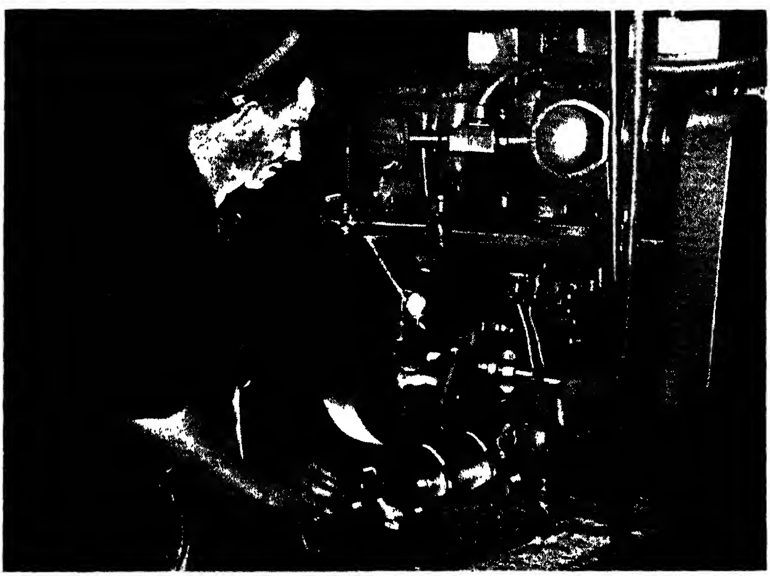

Fig. 10. Milling Two Woodruff Keyways in an Automobile Crankshaft

Woodruff keyways in airplane flap-control gear-shafts, such as seen in the fixture and on the table. After the fixture has been loaded, the table moves quickly to the right to locate the work beneath the cutter for machining the first keyway. The cutter-head then moves downward for the operation, after which it returns to its starting position. The table next travels farther to the right to locate the work for cutting the second keyway, the cutter-spindle again moving downward for this operation and then returning to its starting position. Finally, the table returns to the left, as illustrated, for reloading the fixture. All these movements are started by depressing one push-button. The width of the keyways is 0.1245 inch, plus 0.001 inch, minus 0.0005 inch, while the depth is held to 0.141 inch within plus 0.005 inch, minus 0.001 inch. The cutter is 1/2 inch in diameter.

Example of Spline Milling.— A method employed for milling the splines on airplane propeller shafts is illustrated in Fig. 9. This operation is performed on a horizontal milling machine, with one end of the shaft supported in a soft-jawed chuck and the other end by a center. Attached to the chuck is a dividing head that provides for accurate location of the propeller shaft in milling the successive splines. The splines are cut by a special form cutter, 3 inches in diameter, which is operated at a speed of 51 R.P.M., with a feed of 1 inch per minute. Three cuts are taken to finish each spline, stock to the depth of only 0.002 inch being removed in the final cut.

Milling Two Keyways Simultaneously on Two-spindle Machine.—Two Woodruff keyways are milled at one time in line with each other on one end of crankshafts by the two-spindle milling machine shown in Fig. 10. The two cutter-heads are lowered toward the work at a fast rate, the milling cut being taken at a slower feed. The crankshaft is supported by V-blocks at each end, and is located by the operator's moving a handle on the left-hand side of the machine, which slides an angular block against one side of a crankpin to locate the opposite side against a flat block.

Examples of Straddle Milling.—The straddle-milling of both ends of aluminum alloy forgings is illustrated in Fig. 11. Four cutters are provided, two of which straddle-mill the long boss at one end of the forging, and the other two the narrow boss at the opposite end. The table is

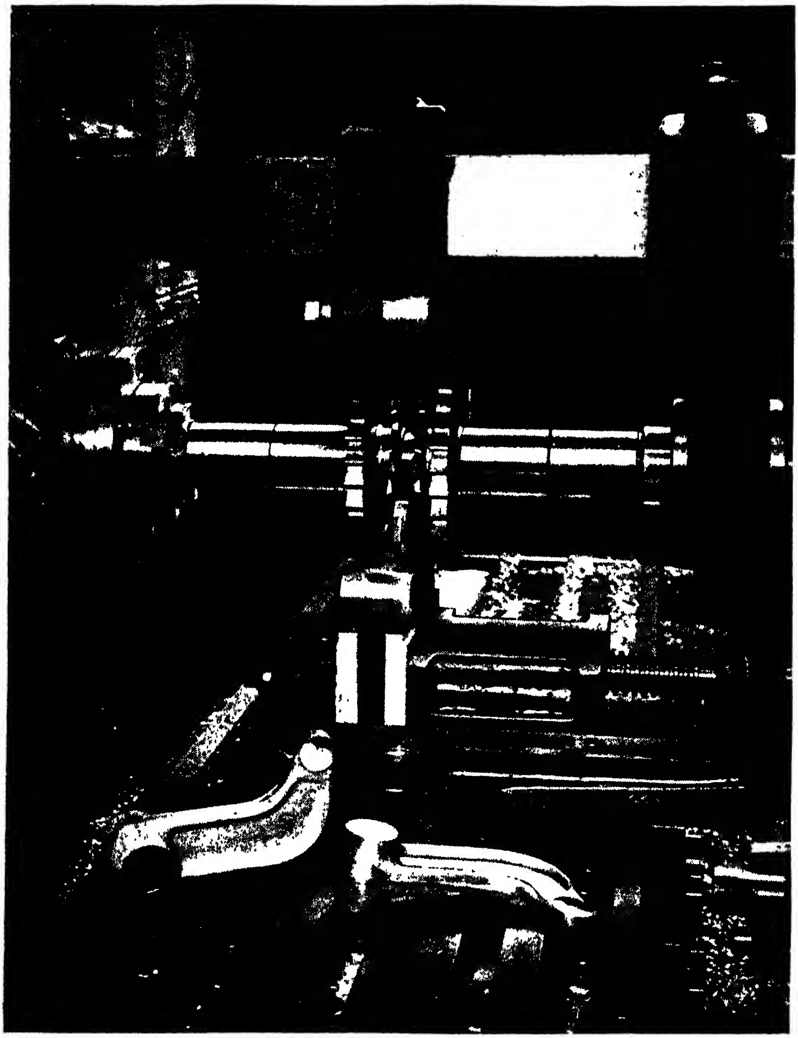

Fig. 11. Double Straddle Milling Operation

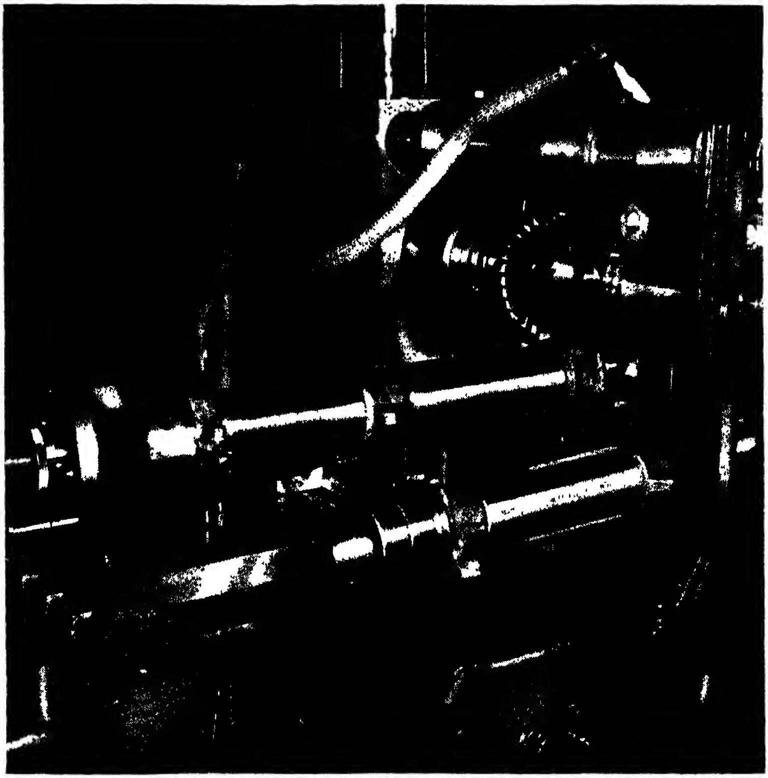

Fig. 12. Milling Lugs on Airplane Landing Gear Strut

operated hydraulically at a fast feed to bring the work to the cutters, and then at a slow feed until the operation is completed. The width of the long boss is held to the specified size within plus or minus 0.002 inch, and the width of the narrow boss within plus or minus 0.005 inch. The relative position of the boss faces must also be held to close limits.

The lugs on airplane landing gear struts are straddle-milled on a machine set up as shown in Fig. 12, which shows a nose strut being milled. The inside and outside surfaces of two lugs are milled at one time, this operation being a finishing one, as the lugs were rough-machined before being welded to the struts. Each inner-lug face must

be the required distance from the center line of the strut within 0.001 inch.

The same fixture is employed for milling the lug seen near the center of the nose strut at right angles to the lugs at the right-hand end. For this second operation, the work is turned to a position located at 90 degrees to the position shown, and a swinging bar is placed between the lugs that

Fig. 13. Gashing and Hobbing Segment Gears

were milled in the first operation, so as to locate the strut accurately. Different cutters are provided, it being the practice to run a group of bars through the first operation, and then the same group through the second. On the main strut, the two sets of lugs are in line and are milled in one set-up. The operation of the milling machine is completely automatic.

Milling a Gear Segment.— The milling operation illustrated in Fig. 13 consists of milling a gear segment on locking dogs for water-tight doors of submarines. A finished dog and a cut-out blank are seen at the right on the table, together with a single milling cutter that is used for gashing out the teeth. In gashing the teeth, one tooth is, of course, cut at a time, the dividing head providing a means of accurately indexing the work from tooth to tooth in relation to the cutter. At the end of the roughing operation, a hob is substituted for the single milling cutter and the dog is so mounted on the spindle of the dividing head that it is free to turn when the hob is fed tangentially through the dog teeth. About eight cuts are taken in this manner to obtain the desired tooth finish and accuracy.

High-speed Milling of Aluminum.— The milling machine illustrated in Fig. 14 is equipped with a high-cycle electric motor drive that gives spindle speeds up to 10,000 R.P.M. This machine applies the fast cutting methods of woodworking equipment to the machining of aluminum-alloy parts. Milling cutters with teeth having a sharp rake and a generous amount of clearance are used.

Sheets of aluminum alloy are scarfed along the edges to the required taper by the milling machine illustrated in Fig. 15, which is equipped with a work-holding fixture that can be tilted to various degrees by merely adjusting the convex bottom surface of the fixture table backward or forward along the concave top of the fixture base. The machine is fitted with a special cutter-head of combined welded and cast construction. The cutter is 4 1/2 inches in diameter by 12 inches long, and is made with teeth of an extremely steep helix, having a generous amount of front

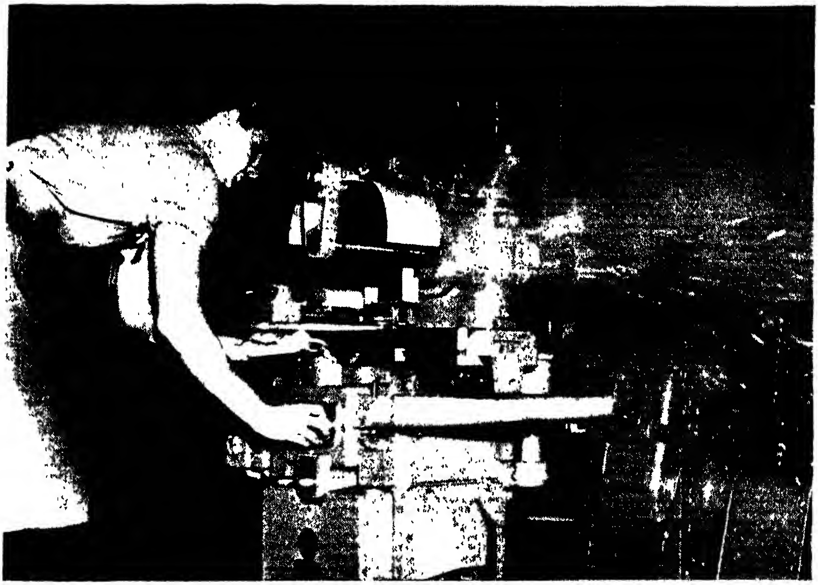

Fig. 14. High-speed Milling of Aluminum Pieces

Fig. 15. Scarfing Sheets of Aluminum Alloy

rake and clearance. With this design, thin shearing cuts are taken without any chatter, the cutter being run at a speed of 600 R.P.M.

Sheets can be scarfed to feather edges with this equipment, the general practice being to scarf to edges about 0.010 inch thick. In operation, the work is first positioned in front of the cutter, and the table is then fed forward to a stop for the scarfing operation, after which it is withdrawn to the front position. The table is next moved longitudinally to bring a new section of the sheet opposite the cutter, and the cycle is repeated. Sheets up to 20 feet long, or as short as 1 1 2 inches, and 1/4 inch thick, are milled in this manner.

Operation Requiring Adjustable Two-spindle Attachment.—Serrations are milled on both sides of the ends of high-pressure, side-locking turbine rotor blades by means of the special set-up shown in Fig. 16 on a plain milling machine. On the over-arm of this machine is a two-spindle vertical cutter unit, the spindles of which can be adjusted in and out by means of a screw provided with right- and left-hand threads. This adjustment enables the set-up man to obtain any required distance between the cutter-spindles. Form milling cutters, mounted on the lower ends of these spindles, mill the serrations across both sides of the turbine blades as the blades are fed between the cutters.

As the serrations must be milled to a radius, the machine is fitted with a special work fixture which is swung at the required arc as the turbine blades are fed between the cutters. The feeding movement of this fixture is obtained by the engagement of a power-driven worm with a long worm segment attached to the under side of the movable member of the work fixture. The operation is completely automatic, except for reloading.

Milling Operations on Horizontal Boring, Drilling and Milling Machines.— On machines of this class, the bed and cutter-driving spindle are horizontal. These machines are employed for boring, drilling, milling, and also used for turning or facing flanges or similar surfaces when such an

operation can be performed to advantage in connection with other machine work on the same part.

The floor type of horizontal boring, drilling, and milling machine is intended for boring heavy parts such as the cylinders of large engines or pumps, the bearings of heavy machine beds, and similar work. This machine can also be used for drilling and milling, although it is intended primarily for boring, and the other operations are usually secondary. This design is ordinarily referred to as the

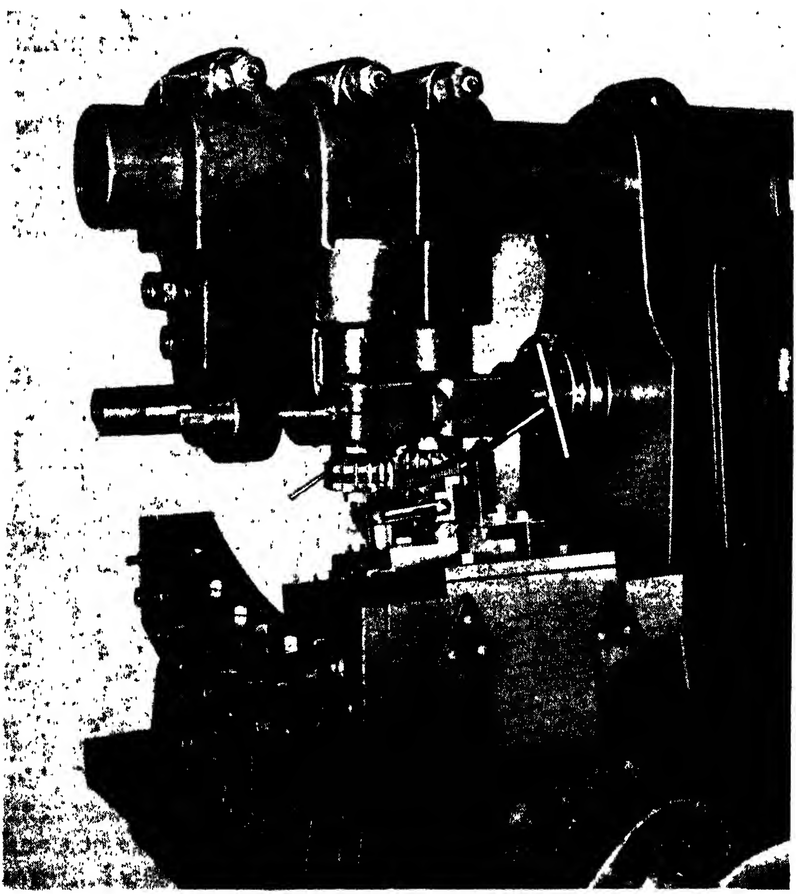

Fig. 16. Milling Serrations on Both Sides of High-pressure, Side-locking Turbine Rotor Blades

Fig. 17. Face-milling a Gun Mount on Horizontal Boring Mill

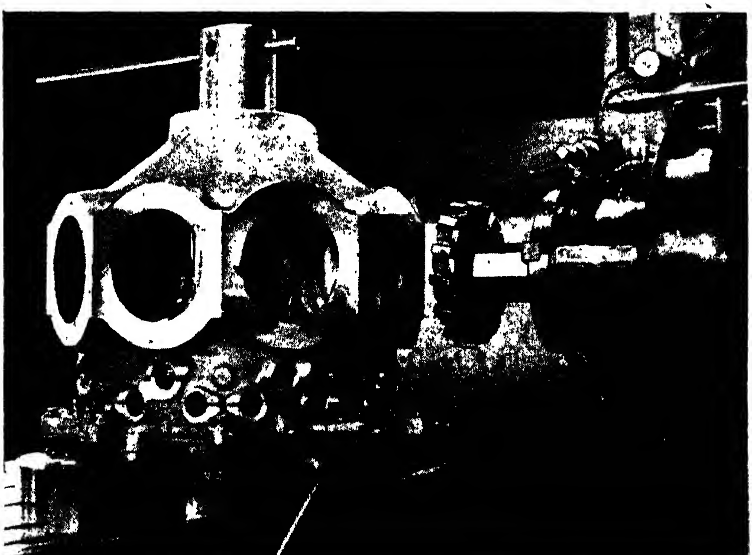

Fig. 18. Milling an Airplane-engine Crankcase on Horizontal Boring Mill

"floor type," because the work table is low for accommodating large heavy castings. The spindle which drives the boring-bar, and the spindle feeding mechanism are carried by a saddle. This saddle is free to move vertically on the face of a column which is mounted on transverse ways extending across the end of the main bed. This construction permits the spindle to move vertically or laterally.

Face Milling Operations.—A typical operation on a horizontal boring, drilling, and milling machine is shown in Fig. 17. It consists of face-milling various vertical surfaces on an arc-welded steel pedestal for an anti-aircraft gun, all faces being held within limits of 0.002 inch as regards their distance from the center of the pedestal. Rough and finish cuts are taken. Boring cuts are also taken on this pedestal with the work set up horizontally. At the left-hand end of the machine table is a second fixture used in boring recoil cradles for guns.

After two crankcase sections for an airplane engine have been bolted together, they are milled and bored to receive the cylinder assemblies, on the horizontal boring, drilling, and milling machine shown in Fig. 18. The illustration shows the machine engaged in milling the large sides of the crankcase to which the cylinder barrels are later bolted, the 7 1/2-inch cutter milling across the entire width of these sides. Small surfaces have previously been milled near the bottom of the crankcase around openings for the fuel injectors and the push-rods. Later, in boring the holes for the cylinder barrels, the boring-bar is guided by a bushing in the center of the fixture. Dowel-holes around the fixture base insure accurate location of the crankcase in each of its twenty-seven indexed positions.

Milling Keyway in Propeller Shaft for Ship.—A ship propeller-shaft keyway is being milled in Fig. 19 with a portable boring, drilling, and milling machine. The propeller shaft is first clamped in large V-blocks on a floor plate, and the boring mill is then brought up to the shaft and lined up parallel with the tapered surface in which the keyway is to be cut. Accurate alignment is obtained by mounting a dial indicator on the spindle of the boring mill and feeding the

indicator along the tapered surface by moving the machine column along its bed, the bed being shifted until it is parallel with the tapered work surface.

In producing each keyway, a rough cut is taken with a helical end-mill that is approximately the full width of the keyway. Then another end-mill is used to finish the keyway all around, only one side being machined at a time. The keyways are cut slightly tapered.

Finish Milling Jaws of Flexible Coupling.—An unusual operation on a table type horizontal boring drilling, and

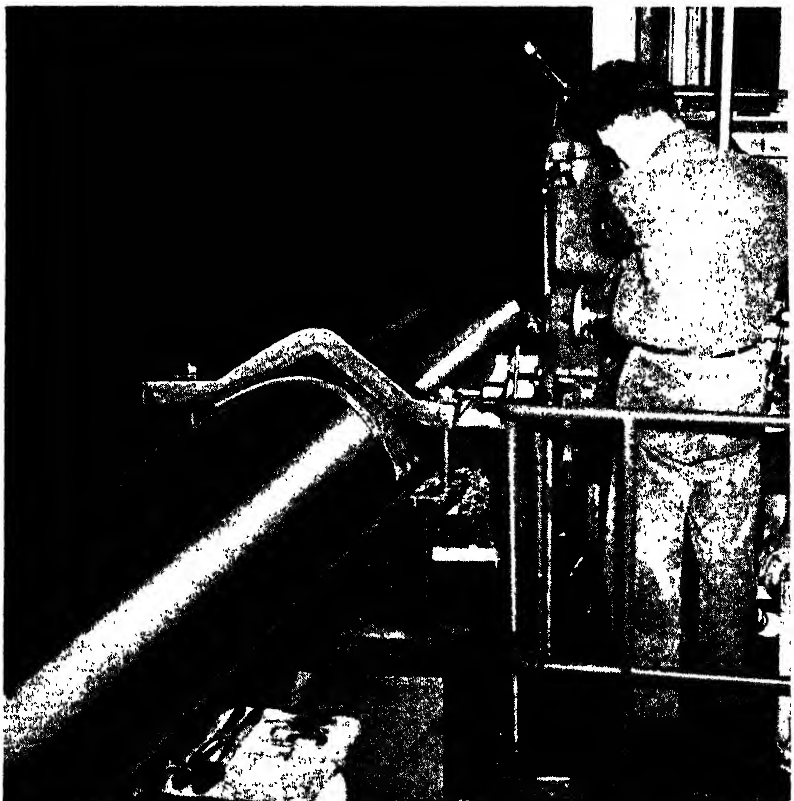

Fig. 19. Milling Keyway in Large Propeller Shaft by the Application of a Portable Boring, Drilling and Milling Machine

milling machine is illustrated in Fig. 20. This consists of finish-milling the jaws of a flexible coupling on one end of a high-pressure turbine rotor. Before this operation is performed, three holes are drilled through the excess stock between each pair of coupling jaws, and the excess stock remaining after the drilling is chipped away by the application of a portable pneumatic hammer. In this way, the amount of stock that must be removed by milling is greatly reduced.

For the milling operation, the rotor is mounted, as illustrated, in the V-grooves of a heavy fixture, which is provided at the left-hand end with a large indexing plate.

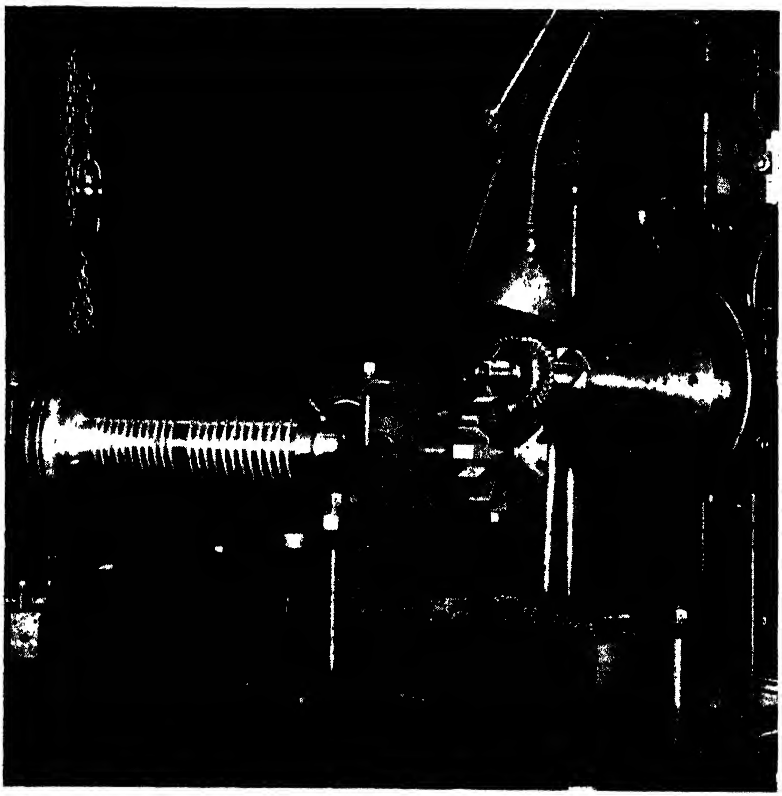

Fig. 20. Horizontal Boring Machine Milling Teeth on a Turbine Rotor Coupling

Bushed holes near the periphery of this plate are used in conjunction with a plug that is slipped through the holes into engagement with the top of a hardened block for locating the coupling jaws successively in line with the milling cutters. Two milling cutters are mounted on the machine spindle for simultaneously milling the opposite sides of each coupling jaw with one movement of the work horizontally past the cutters.

The two side mills used in this operation are approximately eight inches in diameter. The outer corners of the cutters are rounded so as to provide a fillet at the bottom end of the milled surfaces. Because of the heavy weight of the work and the necessity of extending the table a considerable distance beyond the bed, a crane is employed to support the overhanging end of the table. This is accomplished by applying a rope sling to the fixture and attaching the sling to a hook suspended from the crane hoist.

Milling Operations of the Planetary Type. — The form milling (internal or external) of one or more circular surfaces by a planetary movement of one or more milling cutters mounted on an arbor, is known as *planamilling*. The work is held by a stationary chuck; the rotating cutters are fed automatically over or through the work to a set stop, and then fed radially into the work to the proper depth of cut; now the cutter arbor travels slowly in a circle and the cutters mill to an accurately finished diameter. When the cutter arbor has made one complete revolution the cutters are automatically lifted from contact with the work and withdrawn while the work is being changed.

Ball bearing races of the style seen in the lower right-hand corner of Fig. 21 are milled on a machine of the planetary type. This machine is tooled up to accommodate several different sizes of bearing races. Three or four races are chucked at a time on an arbor or in a collet and finished simultaneously at the rate of two or three pieces a minute. One operator can run several machines.

The operation consists of grooving either the inside or outside of the race and, at the same time, finishing the cylindrical surfaces on each side of the ball groove. The

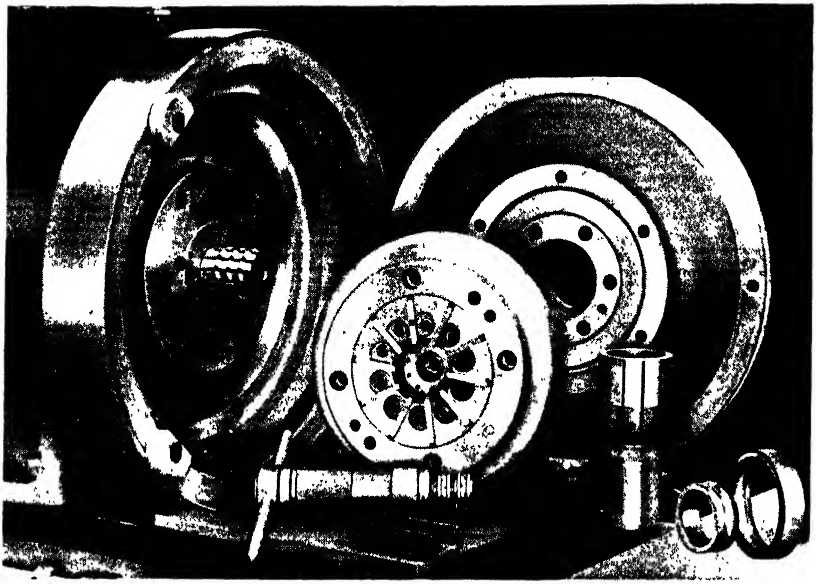

Fig. 21. Tooling Equipment for Planamilling Ball-bearing Races

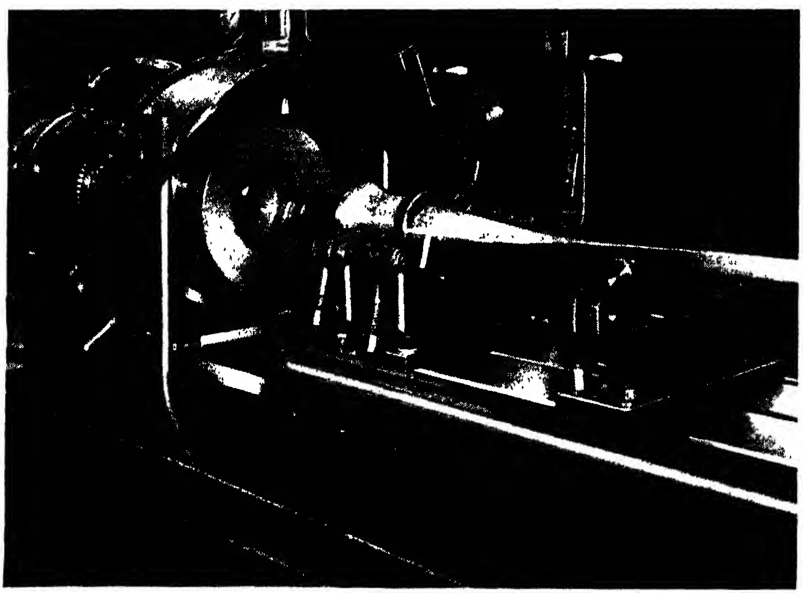

Fig. 22. Form-milling and Facing Shank End of Propeller Blade

dimensions are held within plus or minus 0.001 inch. The cutters are ground to the form of the groove to be produced. The cutter seen in the machine was made for milling three races simultaneously. Tapered roller-bearing races can be handled by substituting the proper cutters.

The operation in Fig. 22 consists of machining the shank end of airplane propeller blades on a planetary machine. This operation, which is the first performed on the blade forgings, involves the use of a series of form cutters that form the flange at the shank end of the blade, as well as the large fillet on the inside of the flange. At the same time, a cutter in the center of the tool-head faces the flange. Both the solid cutter and the inserted form cutters are off center with relation to the work, and they complete the facing and turning in one revolution of the cutters and without any sidewise movement of either the cutters or the work. The work, of course, remains stationary in the conventional manner.

Milling with Single and Multiple Fly-cutters. — Milling may be done by using a single tool or cutting edge shaped to whatever outline is required. This tool is held in an arbor; and as there is only one cut per arbor revolution, the speed of the milling operation is slow in comparison with a regular milling cutter. Notwithstanding this reduction in speed, fly-cutters are often used in preference to form milling cutters because they are easy to make and cost much less than a form cutter; consequently, fly-cutters are commonly applied when the amount of work is not large enough to warrant the cost of the regular form cutter. Fly-cutters are also used in some shops for machining flat surfaces. As a general rule, only one fly-cutter is used but multiple fly-cutters are sometimes employed as shown by examples that follow.

Cutting Sprocket Teeth with Fly-cutter.—Two rows of thirty-two teeth each were cut around a sprocket for a motion picture camera by employing a milling machine set up as shown in Fig. 23. The work was supported at one end by a dividing head which enabled it to be accurately

indexed from tooth to tooth, and the opposite end was held on a regular tailstock. The tooth-cutting was done by a fly-cutter mounted on the spindle of the machine. One tooth space was cut in each row of the teeth with a single feeding movement of the table past the fly-cutter. In other words, both rows of teeth were finished at one complete

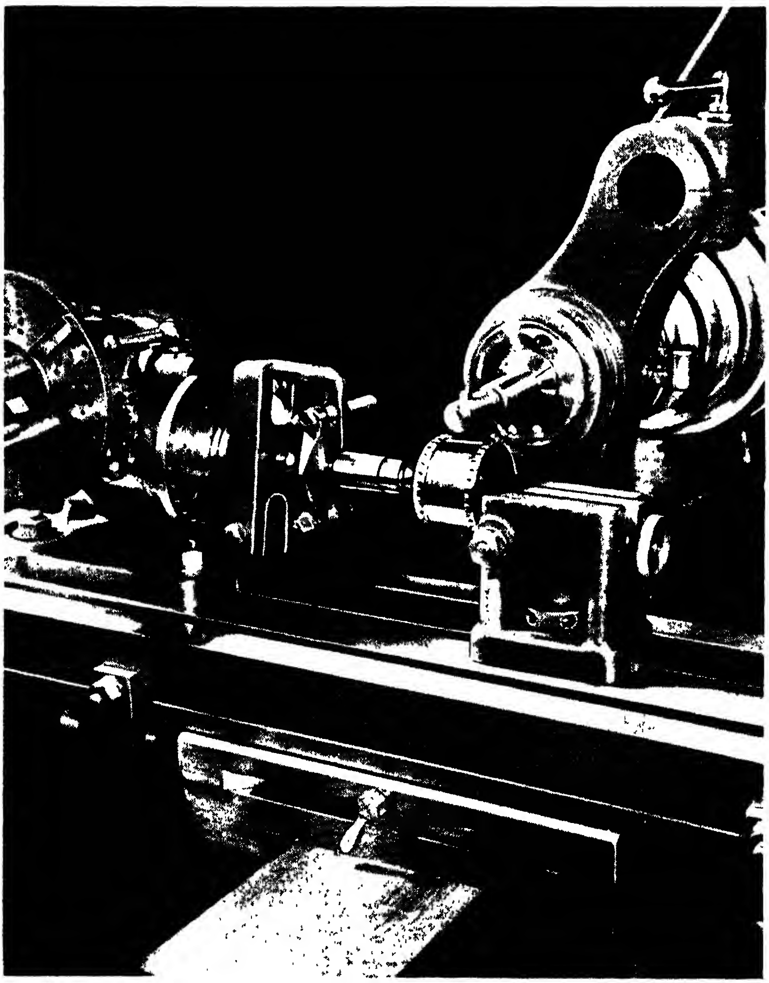

Fig. 23. Milling Two Rows of Thirty-two Teeth Each around a Camera Sprocket

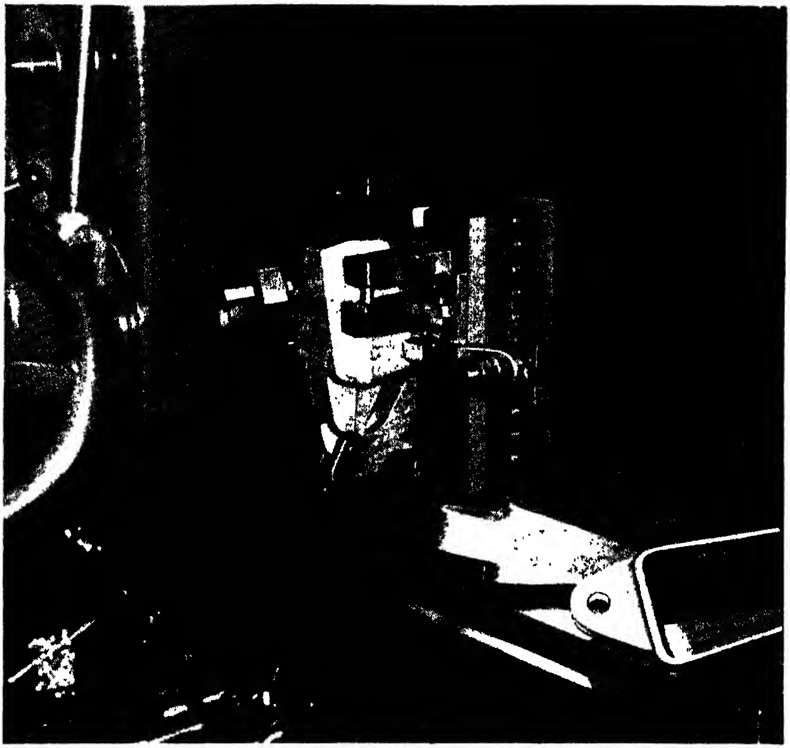

Fig. 24. Machining Flat Surfaces with Fly-cutter

indexing of the sprocket. This method insured close alignment of all teeth in the two rows.

Machining Flat Surfaces with Fly-cutter.—As already mentioned, fly cutting may be used to finish flat surfaces. The flexibility of this tooling principle permits its application to an almost endless variety of work, and surfaces can be finished to a high degree of smoothness and straightness. Another advantage is that the original cutter cost is low and the cutters can be quickly resharpened. Carbide-tipped cutters are commonly used in order to obtain high cutting speeds and a fine finish.

The fly-cutting operation illustrated in Fig. 24 is performed on a boring, drilling, and milling machine. The

work-piece is a forged duralumin boom fitting, and in the set-up shown, two opposite faces are finished. The cutter runs at 1200 R.P.M., and is located on a 7-inch circle which gives a peripheral cutting speed of about 2000 feet per minute. On the table is shown one of the work-pieces as it comes to the machine and in front of it a finished piece after a series of operations performed in different set-ups on the boring mill in which fly-cutters are used for all cuts except boring.

Finishing Flat Surfaces with Multiple Fly-cutter. — A close-up view of an operation on a milling machine equipped with a high-cycle electric motor drive is shown in Fig. 25. In this case, a special head with four slots in which cutters can be adjusted radially is mounted on the machine spindle.

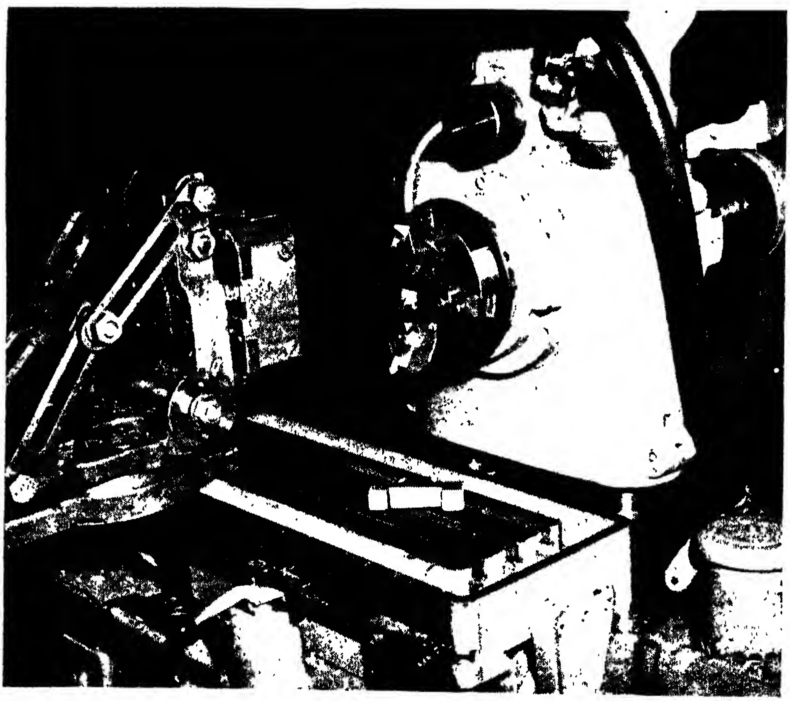

Fig. 25. Finishing Three Surfaces Simultaneously with Triple Fly-cutter on High-speed Machine

The head is shown equipped with three fly-cutters for finishing two flat legs on aluminum castings such as seen lying on the table, and for machining the clearance space between the legs. The work is mounted on the upright face of the fixture at the front of the table, and the operation is performed as the work is fed horizontally past the cutter-head. In this operation, the table is fed at the rate of 144 inches a minute, and the cutters are run at 7500 R.P.M.

Milling with Vertical-Spindle Machines and Attachments

For certain classes of milling, a machine with a vertical spindle is either necessary or preferable to a machine having a horizontal spindle. Vertical-spindle machines are often used for such operations as milling the flat tops of castings with a face-milling cutter or for doing such work as milling grooves or slots with end-mills in horizontal surfaces. Machines with horizontal spindles are sometimes equipped with vertical spindle attachments which are driven from the horizontal spindle. Many of these attachments are so designed that the cutter-spindle may be held either in a vertical position or at an angle for machining angular surfaces.

Milling Square Form, Using Vertical-spindle Machine and Indexing Fixture.— In Fig. 1 is shown an operation on a vertical-spindle milling machine, in which four sides of a bracket are milled to a square cross-section, so as to form mounting surfaces. The four faces must be closely parallel and at right angles to each other, and must be to the specified width in both cross-sectional directions within 0.001 inch. These four faces are successively milled by indexing the work fixture and feeding the work crosswise in relation to the cutter. It is necessary to return the table to the forward position after each surface has been milled, in order to permit the work to clear the cutter as it is indexed into position for milling the next side. Slots are provided in the index-plate at the left-hand end of the fixture to enable the work to be accurately located in the four indexed positions.

Milling Operation on Machine Gun Slide.— In Fig. 2 is shown a vertical-spindle milling machine employed for cut-

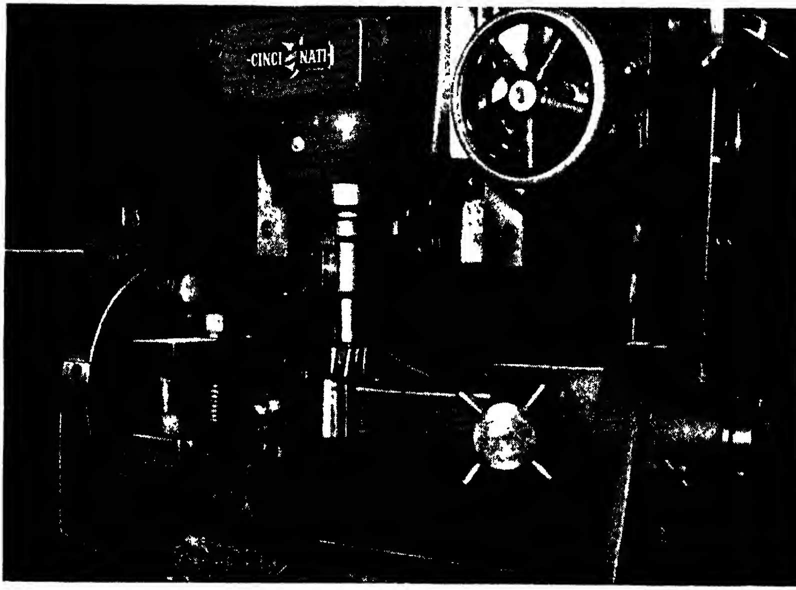

Fig. 1. Milling a Square Cross-section

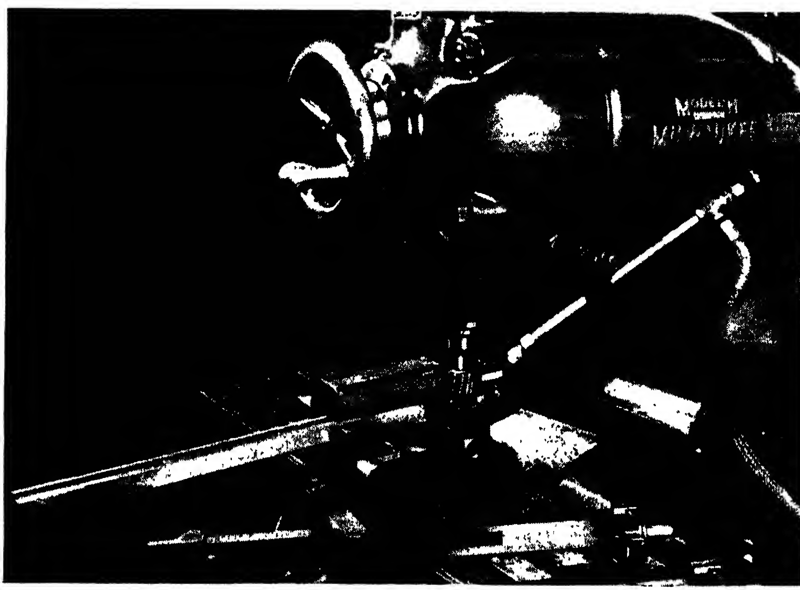

Fig. 2. Milling Operation on Machine Gun Slide

Fig. 3. Milling Truck Axle Housing

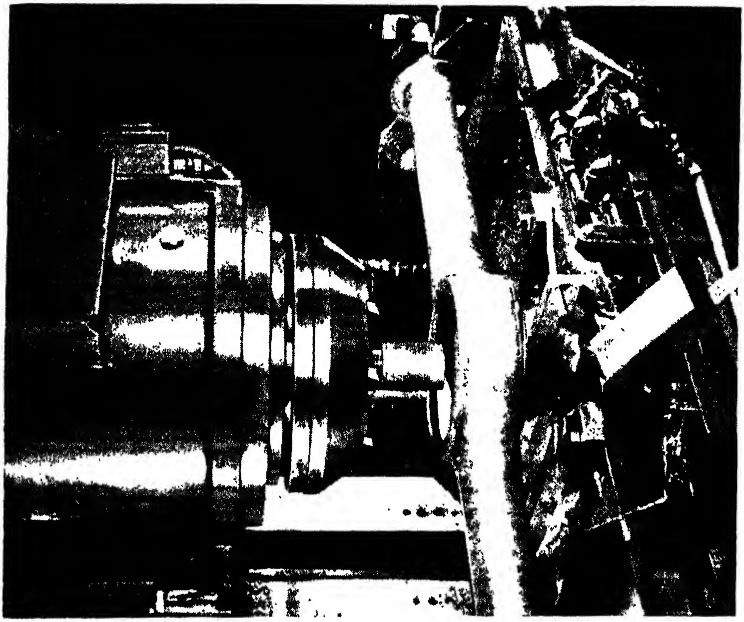

Fig. 4. Face-milling Banjo Faces of Rear-axle Housing

ting through webs of metal on opposite sides of one end of a machine gun slide butt, with such exactness as to blend the surface produced by the face of the cutter with the previously milled surface that extends almost the full length of the piece. The nature of the cut will be apparent from the two examples at the front of the table. This slot is milled to specified width within 0.002 inch. The work-piece is securely supported and located in a fixture by inserting the previously machined round extension on one end into a half bearing in the fixture, in back of the cutter, and also by clamping a long portion of the straight surface against a hardened and ground block in front of the cutter.

Milling Operations on Truck Axle Housing.—The particular operation shown in Fig. 3 consists of milling several pads built up by welding on the body portion of a rear-axle housing, and two additional pads located at an angle of about 80 degrees from the others. With the axle housings in another fixture of the indexing type, square sections between the banjo and each flange are completely milled around the four sides.

The banjo faces of another rear-axle housing are finished one at a time on the machine in Fig. 4, which is equipped with a cutter-head having nine inserted blades positioned around a flat face. With the work loaded in the fixture, the cutter-head is fed downward by hydraulic pressure to a positive stop which controls the height of the finished banjo face above the center line of the axle housing. A pilot on the cutter-head enters a bushing in the center of the fixture for accurately guiding the cutter-head. The work is located by clamping a finish-turned cylindrical surface on the ends of the housing in vees of the fixture and resting the banjo face opposite the one being machined on a hardened and ground bar.

When one banjo face has been milled, the housing is lifted from the vees and slid along rails extending to the front of the machine until it is sufficiently clear of the cutter to permit the banjo to be revolved through 180 degrees. The housing is then replaced in the fixture for milling the second banjo face. The tolerance on the height from a center line

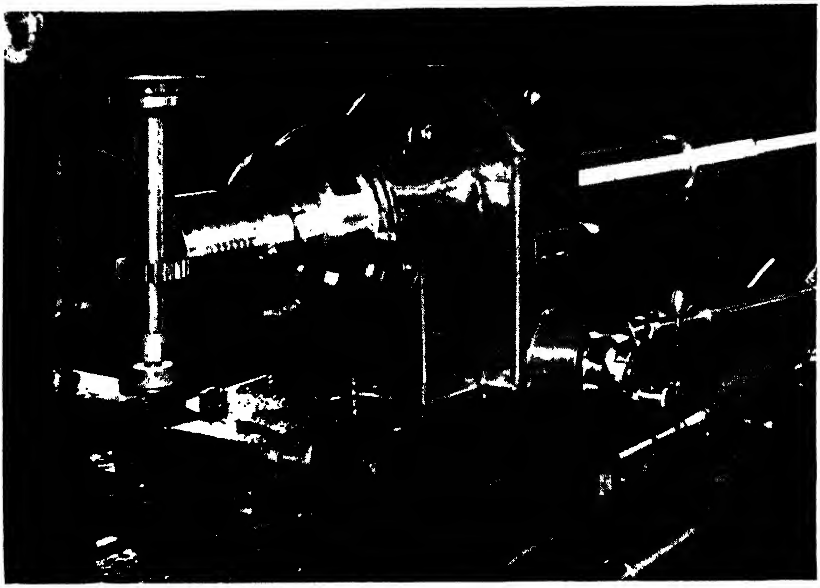

Fig. 5. Milling Slot Across Breech End of Anti-aircraft Gun

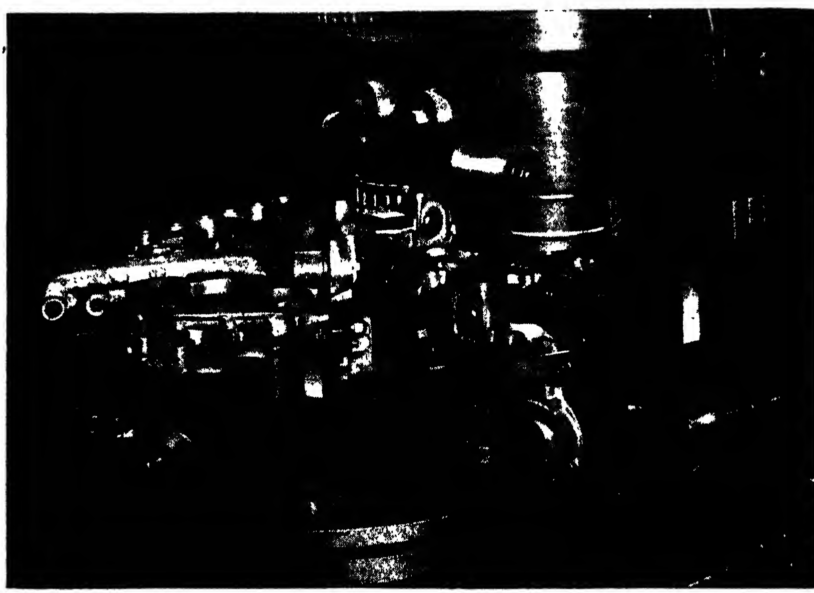

Fig. 6. Examples of Rotary Milling

passing through the machined axles to the banjo faces is 0.010 inch.

Milling Slot in Breech End of Anti-aircraft Gun.—In Fig. 5 an anti-aircraft gun barrel is shown on a vertical-spindle milling machine for milling extractor slots on the breech end and also for milling the locking slot and abutment faces. The breech end of the gun barrel is held in a special work fixture of indexing type. The muzzle end is supported by a large bracket near the outer end of the table, a sleeve being slipped on the barrel to protect the finish at the point where it is supported. All milling must be performed in relation to the point where the external thread starts. Set-ups are made by means of indicators.

Milling with Machines of Vertical-spindle Rotary Type.—Castings or forgings which are so shaped as to be readily clamped or released from a fixture are sometimes milled by a continuous circular milling operation. The continuous rotary milling machine is intended for milling large quantities of duplicate parts. The castings or forgings to be milled are held in a fixture (or fixtures) near the edge of the table and, as the latter revolves, one piece after another passes beneath the revolving cutter (or cutters) and is milled or faced. As the finished parts come around to the front of the machine, they are removed by the operator and replaced by rough pieces without stopping the machine, so that the milling operation is practically continuous. A fixture for continuous circular milling must be designed so that the work can be removed quickly and without stopping the rotation of the table. The increased production that has been effected in many cases by substituting continuous rotary milling for some other method is due to reducing the non-productive time of the machine by avoiding the necessity of stopping to set up work and then restarting the machine; by avoiding the need of returning the table to the starting point after each traverse; and by overcoming the necessity of having the machine idle while the operator is setting up work, or the operator idle while the machine is running.

Examples of rotary milling are illustrated in Fig. 6.

This photograph was taken in a new tractor plant where manifolds are rough- and finish-milled in three positions of the machine, and housing covers in five positions, there being eight fixtures of different designs on the table. The roughing cutter is fitted with Stellite J-metal blades, and the finishing cutter, with blades of high-speed steel. The operation is a continuous one.

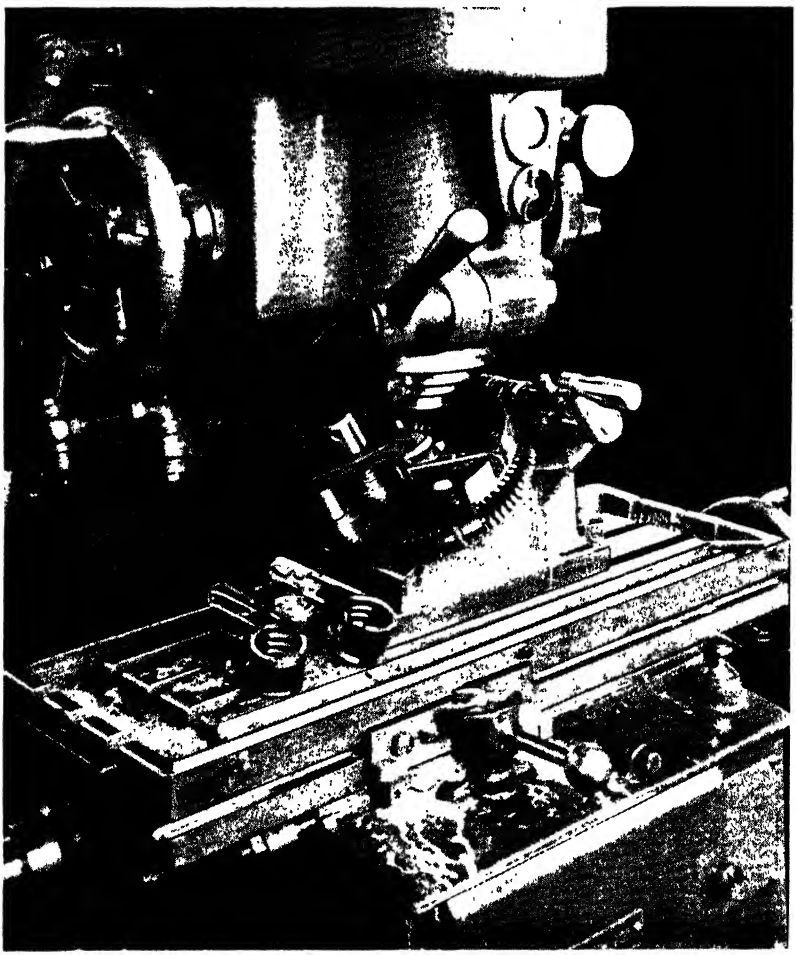

Fig. 7. Milling Angular Surface on Circular Boss

Rotary Fixture for Milling a Beveled Circular Surface.—An interesting machine set-up, employed for milling a beveled surface part way around a circular boss, is shown in Fig. 7. The machine is a vertical-spindle milling machine equipped with a fixture having a worm drive, which is operated by turning a crank-handle to revolve the work past the cutter through the required arc. Stops limit the rotating movement of the table. The face of the fixture is inclined, so as to present the end of the boss being milled at the desired angle to the cutter.

Face Milling Operation.—The fork surfaces on the end of airplane wing terminals are finished in several operations. The first of these is shown in Fig. 8. The operation is performed on a vertical-spindle milling machine and consists of finishing one of the outside fork surfaces to establish the desired angle of the yoke with respect to the center line through the shank. The work is accurately located in the fixture from the ground shank surfaces. Approximately 1/16 inch of stock is removed. In this operation, the table saddle feeds toward the machine column to carry the work under the cutter. Following this, the terminal is placed in a jig and finish-milled on the inside of the fork.

Milling Compound Angle.—Fig. 9 shows a milling machine being used for milling the edges of steel die-plates to required angles by tilting the milling head and using the side of an end-mill. By positioning the work at an angle with respect to the length of the table, the edge of the plate is machined to a compound angle in one cut. The die-plates are milled to different angles along the front, back, and sides.

Vertical Milling Attachments.—There are several types of vertical attachments designed for various classes of work. The principal difference between these designs, aside from minor details, is in the adjustment of the cutter spindle. There is a compound type of vertical spindle attachment which is adjustable in two vertical planes, one being parallel with the axis of the spindle, and the other being at right angles to the spindle. The universal milling attachment is so named because the spindle can be set at any

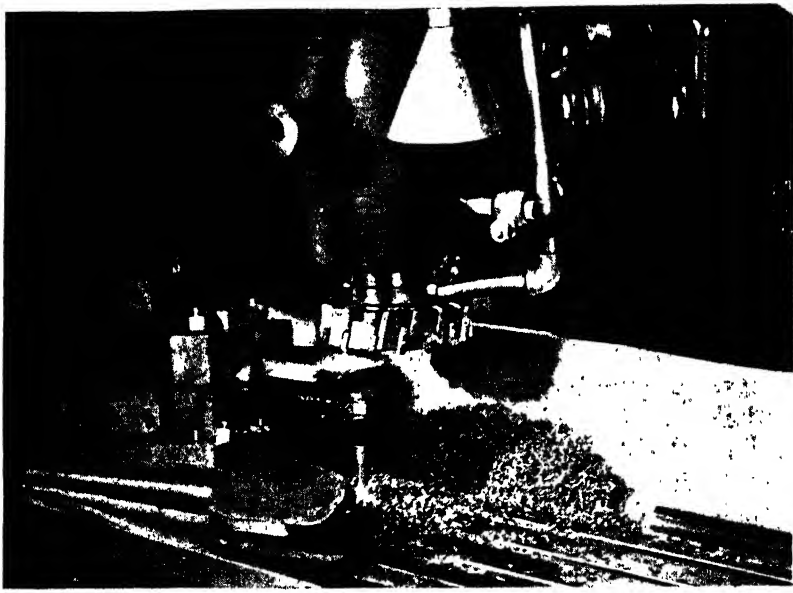

Fig. 8. Face Milling Side of Fork

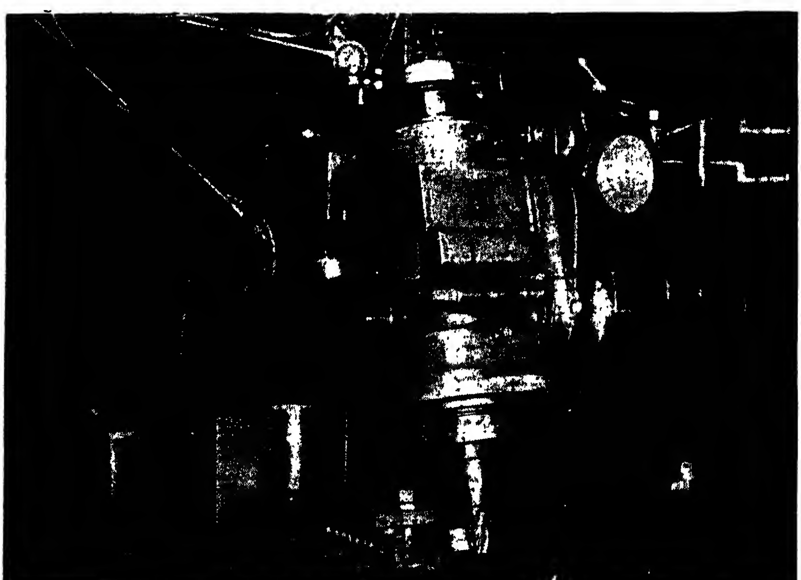

Fig. 9. Milling Die-plate Edges on Universal Milling Machine

angle in both horizontal and vertical planes. A horizontal milling machine equipped with a universal milling attachment is shown in Fig. 10 set up for an operation on a motion picture projector. The operation consists of milling the inside surfaces of two lugs with an end-mill that is positioned at an angle of 10 degrees.

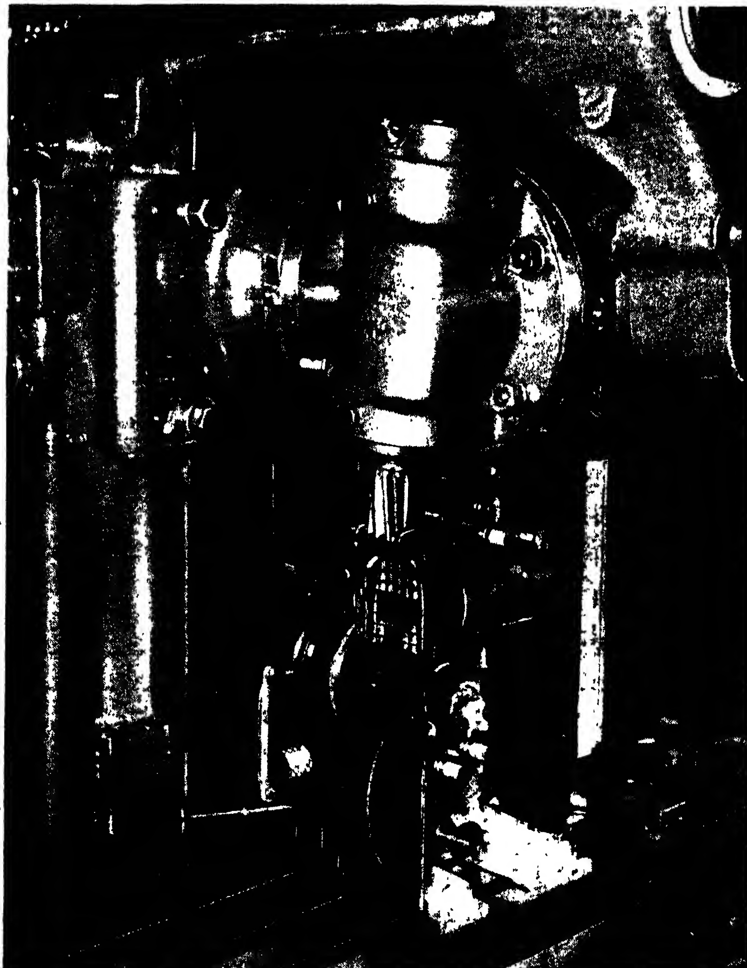

Fig. 10. Typical Operation Performed on a Milling Machine Equipped with a Universal Attachment

Multiple-Spindle Milling Operations

Milling machines for producing duplicate parts in manufacturing plants are provided in many cases with two or more cutter-spindles so that different sides or surfaces can be milled simultaneously. For example, some machines have two spindles which are opposed or directly opposite for milling both sides of a casting or forging. Other machines have parallel vertical spindles and some types have both horizontal and vertical spindles. A few examples of multiple-spindle milling are included in this section.

Milling Elongated Slot with Double-end Spline Miller.—An elongated slot is milled through the solid stock of the piston extension of a machine gun, by using a double-end spline miller arranged as illustrated in Fig. 1. This slot, which is seen at the left-hand end of the work-piece at the front of the cross-slide, must be milled to a width of approximately 0.500 inch, within 0.008 inch, for a length of nearly 3 inches completely through the piece, except for a thickness of about 1/32 inch on one side. Then, in a second operation, this thin wall is cut through for a length of about 1 11/16 inches. Both operations are performed on the same type of machine.

In the first operation, which is the one illustrated, the end-mills are fed into the work until there is a wall thickness of only 1/32 inch on the far side of the piece, after which the cross-slide is fed toward the rear of the machine under hydraulic pressure to cut the slot to the required length. Two pieces are machined at the same time by end-mills in the opposing spindles of the machine. One end of

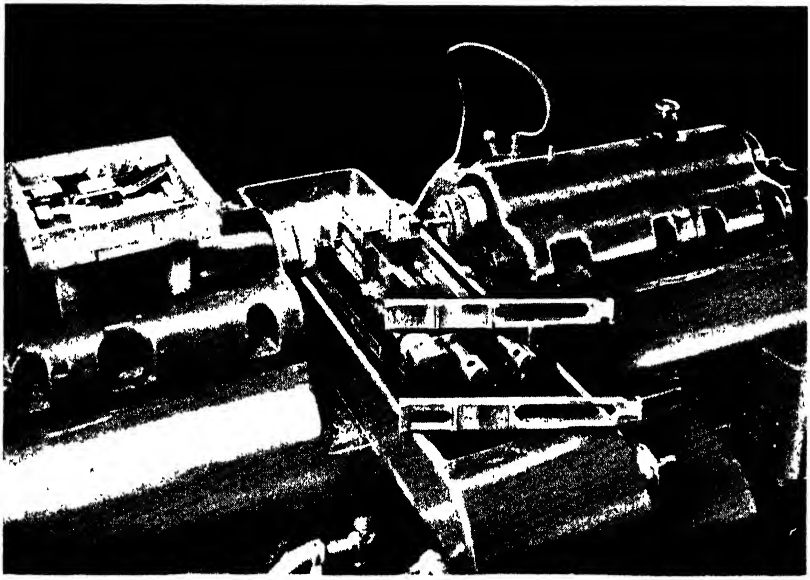

Fig. 1. Slot Milling on Double-end Spline Miller

Fig. 2. Example of Work on Duplex Milling Machine

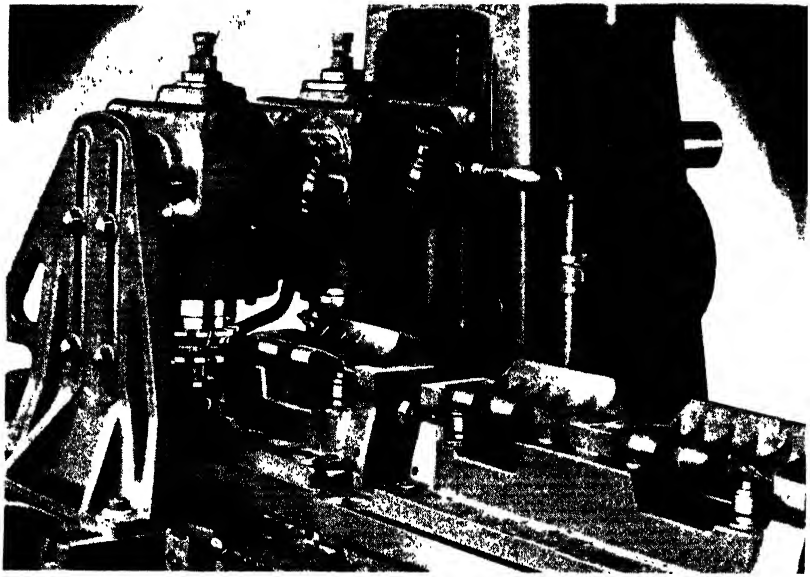

Fig. 3. Milling with Two-spindle Attachment

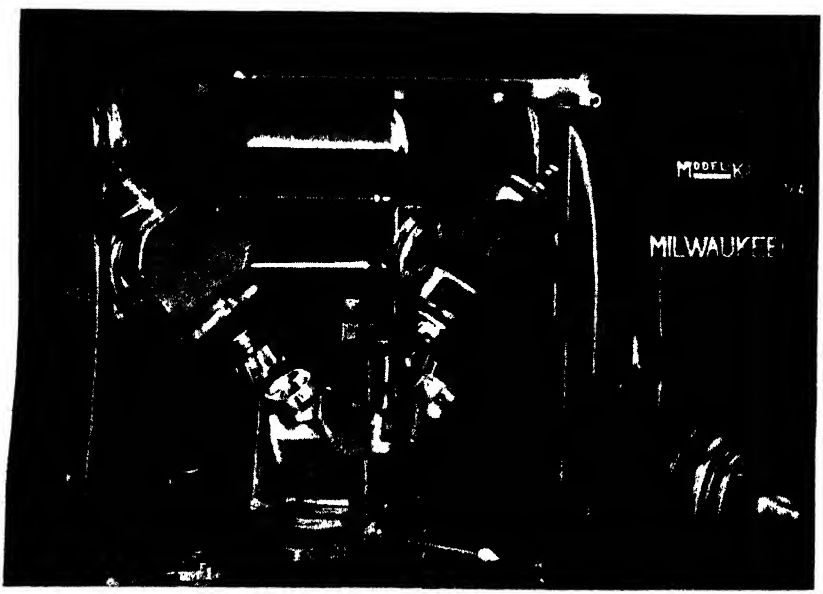

Fig. 4. Milling Angular Pads

each piece is located from a hardened and ground block at the back of the fixture, against which the parts are forced by tightening adjusting screws against the front ends. The ends of the parts adjacent to the locating block are supported for a length of about 3 inches, and the parts also rest on machined lugs about 1 inch wide near the front end of the fixture. Except for the actual cutting, the second operation is identical with the first.

Face Milling on Duplex Machine.—The milling operation shown on the duplex milling machine, Fig. 2, consists of simultaneously finishing the opposite ends of cast-steel suspension brackets for military tanks. Four of these castings are held on the table fixtures. Two inserted-blade face-milling cutters of 10 inches diameter are mounted on the opposed spindles of the machine.

Example of Milling with Two-spindle Attachment.—Form cutters on the two-spindle milling machine shown in Fig. 3 mill small-diameter cylindrical surfaces on the opposite sides of steel forgings simultaneously as the table of the machine feeds along beneath the cutters. Each forging has four of these cylindrical surfaces, two on each side.

The two-spindle vertical attachment is driven from the main spindle nose through a gear. The spindle heads can be removed when a standard machine is desired for any type of milling operation within its range. The outer spindle can be adjusted vertically.

Angular Milling Operation.—Two inclined pads on cylinder heads for airplane engines are milled simultaneously by the milling machine illustrated in Fig. 4. The milling heads can be swiveled to obtain the desired angular settings. They can also be adjusted with respect to center-to-center distance, and their spindles are contained in quills that can be adjusted individually to and from the work. A special work-fixture is supplied.

Special Duplex Type of Machine.—A milling machine of unusual design is employed by a tractor company for mill-

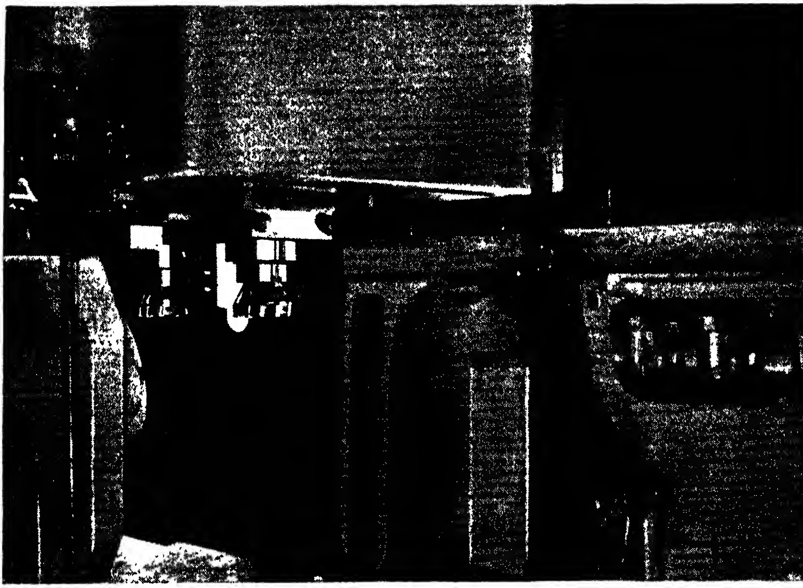

Fig. 5. Left-hand Head of a Double-head Machine

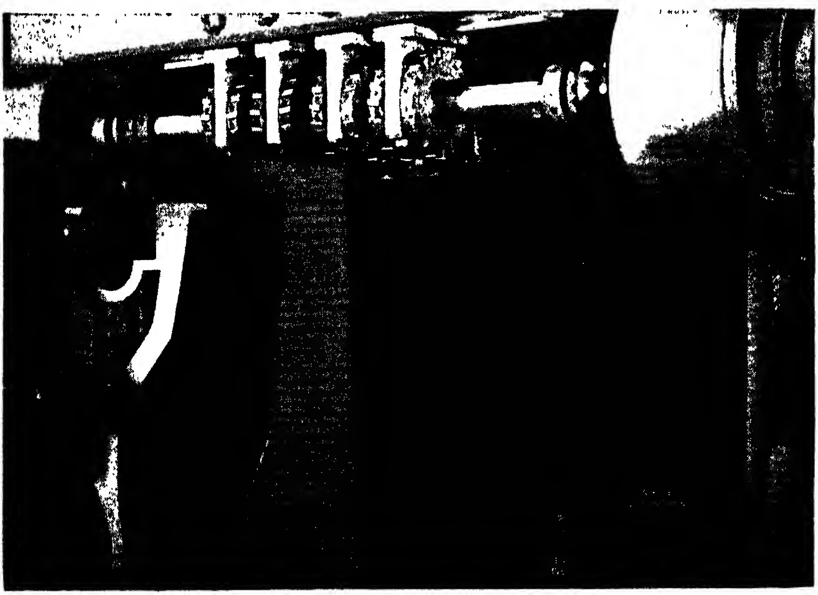

Fig. 6. Right-hand Head of Machine Shown in Fig. 5

ing various surfaces on the crankcase or bottom side of cylinder blocks. This machine is built with two heads which span the base. The work is carried by the table first beneath the cutters of one head and then beneath those of the other head.

In the first step of this operation, the cylinder block is fed past the left-hand head, shown in Fig. 5, which is provided with two cutters that revolve in a horizontal plane for milling the bearing faces to receive the caps, and two cutters that revolve in vertical planes to mill the bearing-lock surfaces. At the same time, a cutter on the front side of the machine mills pads on the angular side of the casting. These pads extend around openings in the cylinder block, as may be seen at the right.

When the table recedes from these cutters, it carries the cylinder block to the opposite milling head which is equipped, as shown in Fig. 6, with a horizontal arbor on which there is a series of cutters for milling all the bearing faces or bosses simultaneously. The table advances until the center line of the bearings coincides with the center line of the cutter-arbor. Then the table stops and the milling head feeds downward. Upon the completion of the cuts, the head rises and the table again feeds toward the left-hand milling head.

A double work fixture is provided on this machine, as the cylinder must be presented lengthwise to the cutters of the left-hand head and crosswise to the cutters of the right-hand head. While one operation is being performed on one fixture, the opposite fixture is being unloaded and loaded.

Milling Channels in Airplane Engine Connecting-rods.—The milling machine illustrated in Fig. 7 is tooled up for milling simultaneously the channels in four articulated connecting-rods of an airplane engine. In the operation sequence, the cutter-head feeds the four end-milling cutters downward to depth, and then in a straight path from the wrist-pin boss to the knuckle-pin boss of each rod. The full width of the channels is milled in one pass of the cutters. At the end of the milling operation, the cutters rise, and

the cutter-head recedes to the starting position. This machine is provided with eight fixtures, so that four of them can be loaded while an operation is in progress.

Applications of Drum-type Milling Machines.—Cylinder heads are milled on the top and bottom, and cylinder blocks on the ends, in the drum type milling machine shown in Fig. 8. The rotary drum is provided alternately with two types of fixtures, one being designed to hold a cylinder block crosswise on the drum, as shown, while the other is designed to hold cylinder heads on both sides of the drum, first on the right-hand side for milling the top and then on the left-hand side for milling the bottom. Two cutters, the

Fig. 7. Milling the Channels in Four Articulated Connecting-rods

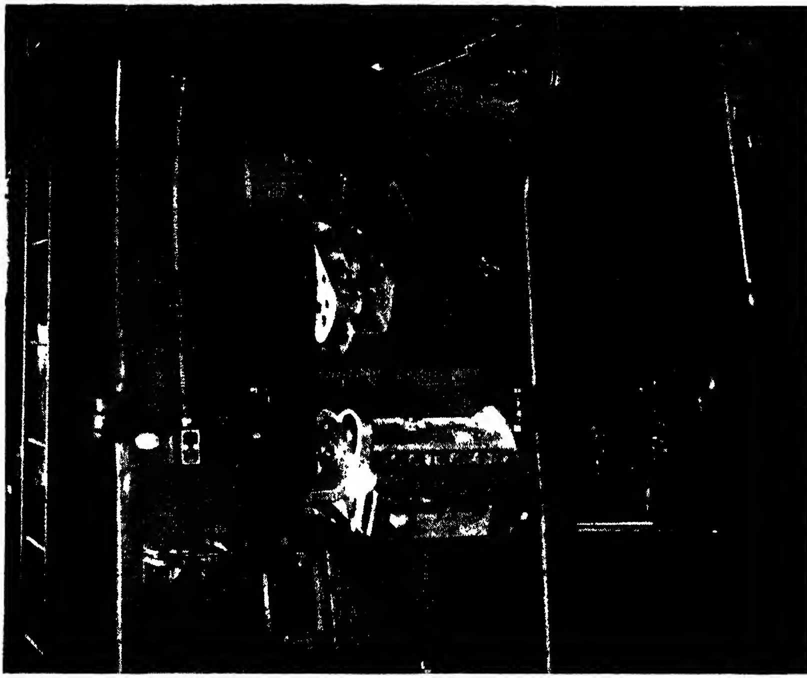

Fig. 8. Drum Type Milling Machine that Finishes the Ends of Cylinder Blocks and the Top and Bottom of Cylinder Heads for Tractors

larger 14 inches in diameter, are mounted on each side of the machine.

Machine gun barrels in one plant are produced from bar stock of S A E 4150 steel, which is cut up to lengths of approximately 24 1/8 inches on a hydraulic sawing machine. The bars are heat-treated to a hardness of 300 Brinell before any machining is performed. The first machining operation consists of milling the bars to length within close limits in the drum-type continuous milling machine shown in Fig. 9. The bars of stock are loaded on the revolving drum at the top, which carries them down around the back of the machine past rough-milling cutters that operate on the opposite ends. The bars then continue moving up past finishing cutters at the front of the ma-

chine that mill the opposite ends. Link chains hold the pieces in place as they move around the machine.

One of the finishing cutters may be seen in the illustration. The roughing cutters remove from 1/32 to 1/16 inch of stock from the bar ends, while the finishing cutters merely clean up the ends. The milling cutters are of the inserted-blade type, and are 6 inches in diameter.

Vertical- and Horizontal-spindle Machine for Milling Three Sides Simultaneously.— A machine for milling three sides of tractor transmission cases simultaneously is shown in Fig. 10. The three cutter heads are driven individually by 50-horsepower motors. Two cutters 36 inches in diameter

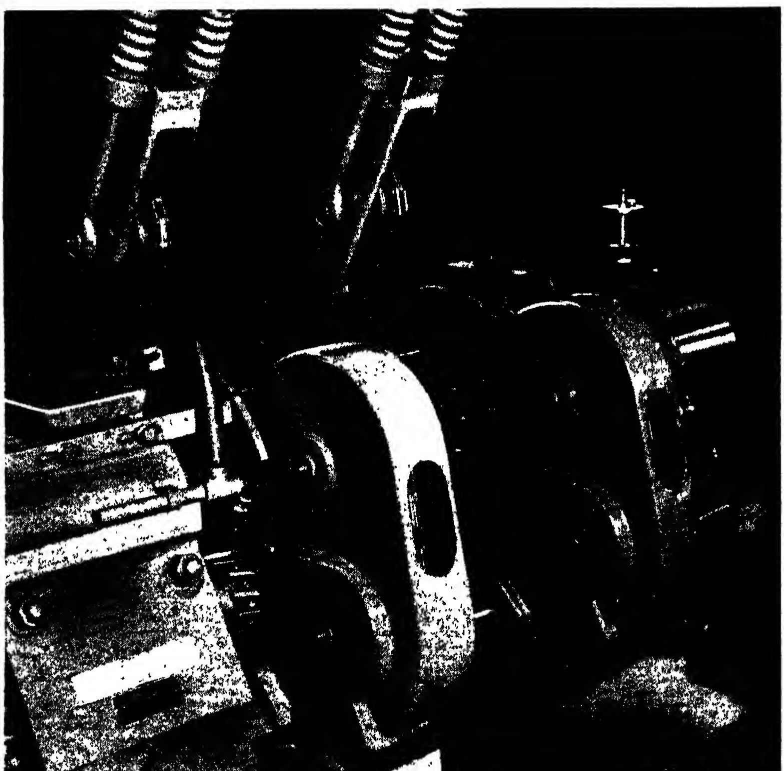

Fig. 9. Drum Type Continuous Milling Machine which Finishes the Ends of the Gun Barrel Stock to Length

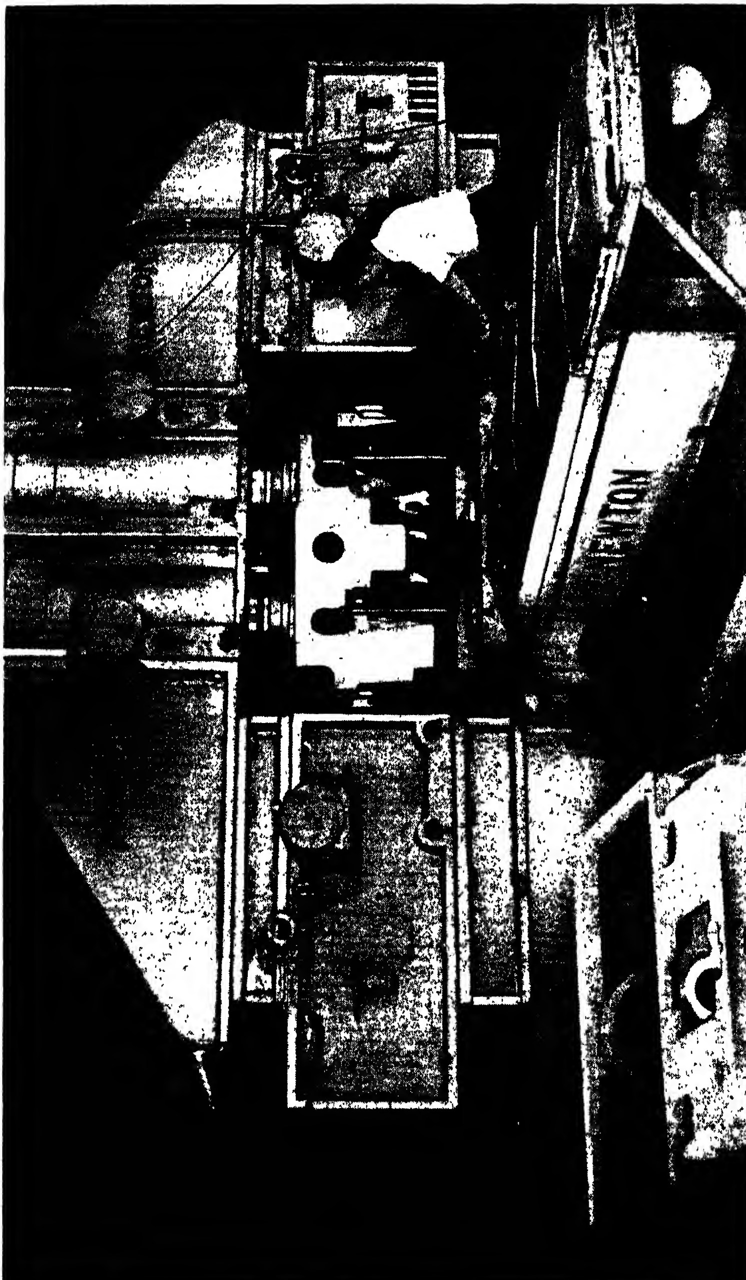

Fig. 10. Milling Machine in which Cutters up to 36 Inches in Diameter are Used for Machining Three Sides of Transmission Cases Simultaneously

finish the top of the case in conjunction with a smaller cutter at the back of the head, which mills away the narrow band of stock left between the paths of the two larger cutters. At the same time, 32-inch diameter cutters mill the sides of the transmission case. All of these cutters are provided with Stellite blades.

Two operations are ordinarily performed on two different transmission cases in this machine, it being merely necessary to adjust the spindle quills to suit. Should it be necessary to adapt the machine for wider work, this could be accomplished by moving the side-heads farther apart

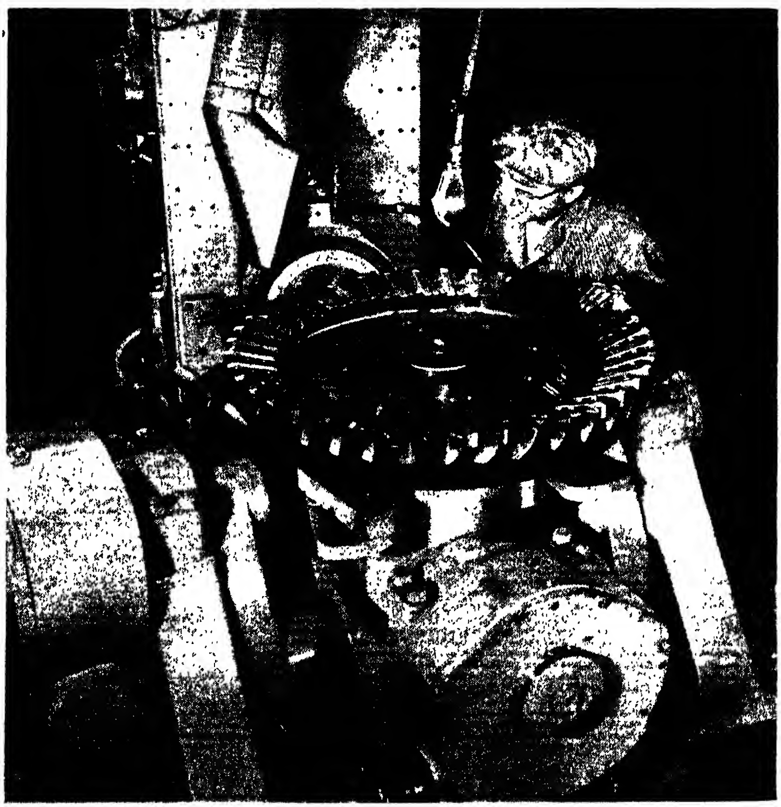

Fig. 11. Hydraulically Operated Machine for Sharpening Milling Cutters up to 40 Inches in Diameter

on the machine base and rebolting. The spacers between the base, side-heads, and crown rail could be removed to reduce the height from the table to the crown rail, or thicker spacers could be provided to increase the height. This milling machine has a weight of approximately 110,000 pounds without the motors.

Three special machines were built for sharpening the huge cutters used by this milling machine and others throughout the plant. One of these machines is shown in Fig. 11. It is equipped with a grinding head that is fed up and down on the column in relation to the cutter teeth by hydraulic power. The work fixture is completely universal in that it can be tilted to any compound angle required. It is hand-operated in and out on the bed-ways, and is hand-indexed. Cutters up to 40 inches in diameter can be accommodated.

Milling Irregular Forms by Reproducing Shape of Model

Some irregular forms are milled by reproducing the shape of a master templet, model, or master cam. The irregular surface to be milled may be around the edge of a templet, plate, pattern, etc., or it may form the cavity in a die or mold. Such irregular shapes cannot, of course, be formed by merely reproducing the shape of a cutter, as a general rule; hence, some form of master or model is used, especially when duplicate parts of an irregular form must be milled. The exact method of copying the master or model varies with different types of machines. In most cases, a tracer finger or pointer moves along or over the irregular model and its motion is reproduced by a milling cutter operating upon the work. The tracing point may be controlled manually or automatically, depending upon the type of machine, and the milled part may, or may not, be the same size as the model. The size of the work relative to the master or model, the form of the milled surface, and the quantity of work are considered in selecting the type of machine. Several different types are shown in the examples to follow.

Milling Cam to Contour of Master Cam.—The vertical milling machine shown in Fig. 1 is equipped for automatically milling cams of the type seen on the front of the machine knee. A master cam is mounted at the right of the table fixture for imparting vertical movements to a tracer as the cam revolves and as it is fed toward the left. This tracer operates hydraulic valves, causing similar movements to be imparted to the cutter-spindle, so that the work-piece is milled to exactly the same contour as the

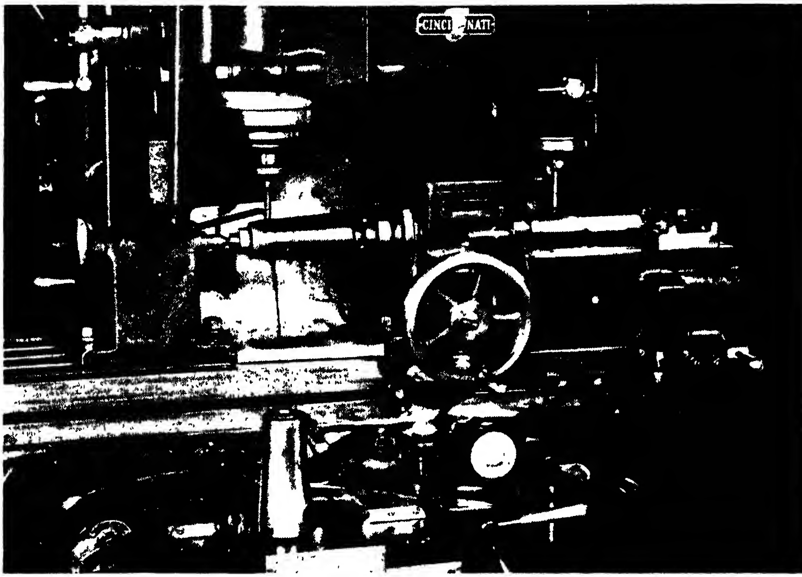

Fig. 1. Milling Cams from a Master

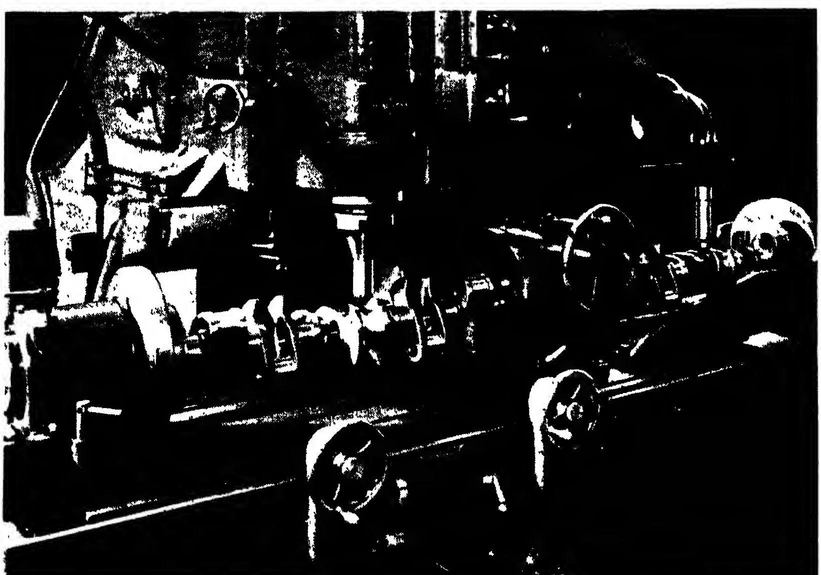

Fig. 2. Beveling the Edges of Crankshafts

master cam. The end of the cutter is ground to the same outline as the tracer, and it is of the same diameter, 1/4 inch. It is made with two flutes. The cams are produced from a Nitralloy steel. It required approximately two weeks for rough- and finish-milling these cams by the methods formerly used, whereas with the machine shown, the roughing cut can be completed in one day and the finishing cut in another day.

Milling Beveled Surfaces on Crankshafts.—The edges of all cheeks on the crankshafts for a certain aircraft engine are milled to a 45-degree bevel in a milling machine arranged as shown in Fig. 2. The angular milling cutter in the vertical spindle of this machine is guided automatically around the changing contours of the crank cheeks as the spindle-carrier unit or cross-slide moves in and out and the spindle-carrier or vertical head moves up and down. These spindle movements are controlled automatically as a tracer on a bracket fastened to the right-hand side of the spindle head follows the cheeks on a master crankshaft held in a fixture at the right-hand end of the table. This operation is completed on a crankshaft in approximately two hours, whereas when the edges of the cheeks were filed by the previous hand method, about twenty-seven hours were required for one crankshaft. All sliding units of the machine, that is, the cross-slide, the vertical head, and the table, are actuated hydraulically.

Milling Irregular Shape on Profiling Machine.—In Fig. 3 is shown an operation performed on a profiling machine. It consists of rough- and finish-milling the edges of the bosses at the opposite ends of a link forging, and also one side of the center boss. The tool is guided sidewise in the required path by a former pin, mounted at the right of the tool, which follows the form of a templet on the table at the right of the work. The work-table is moved in and out with respect to the cutter, and the latter is moved sidewise as required for performing the job.

When the work has been rough-milled with the tool seen in line with the work, this tool is fed to the right, out of

the way, and a second cutter-head with its former pin, at the left, is brought into position for taking the finishing cut.

Profile Milling on Hand Milling Machine.—Hand milling machines are applicable to machining a wide variety of small parts. In Fig. 4, a hand milling machine is shown tooled up for milling a cam slot in small steel plates. The milling cutter is guided in the proper path to cut the slot to the desired outline by the engagement of a hardened pin with an identical slot in a templet that is mounted on the same fixture as the work. The guide pin is of the same diameter as the milling cutter. The machine table moves

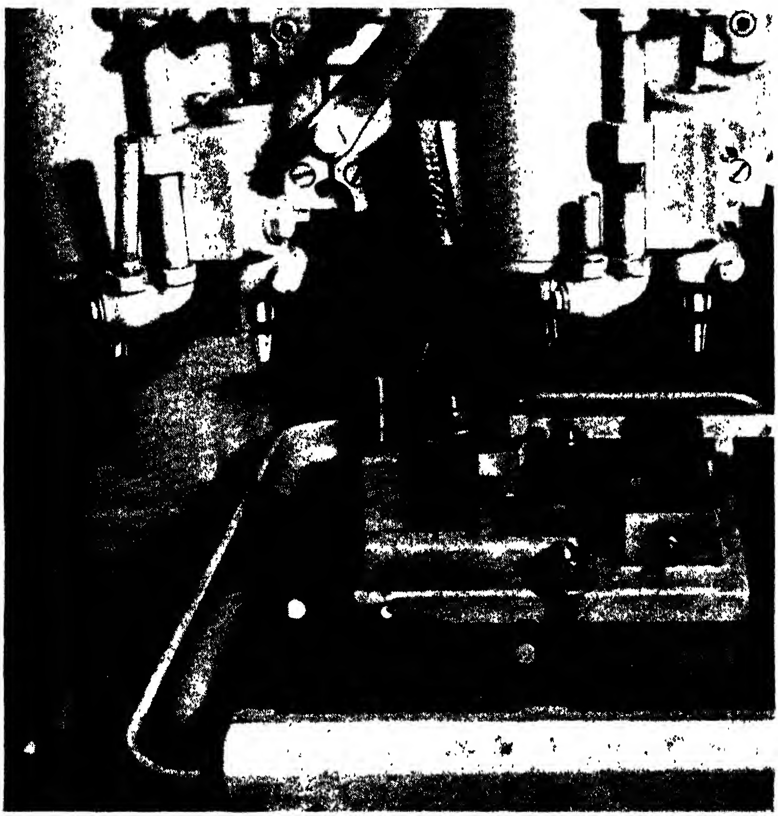

Fig. 3. Typical Profile Milling Operation, in which Roughing and Finishing Cuts are Taken

up and down as the fixture is fed to the right or left when the operator manipulates the handles on the front of the table and on the vertical slide.

Duplication of Master Templet Automatically by Electrical Control.—The channels in airplane-engine master

Fig. 4. Hand Milling Machine Applied to the Milling of Cam Slots in Steel Plates through the Provision of a Guide Roller and Templet for Controlling the Cutter Movements

rods are milled under the control of a tracer by the machine shown in Fig. 5. The tracer is mounted on the right-hand side of the tool-head and slides in engagement with a templet mounted on an adjustable auxiliary table. The entire operation is performed automatically, the movements of the tracer being duplicated by the two cutters through

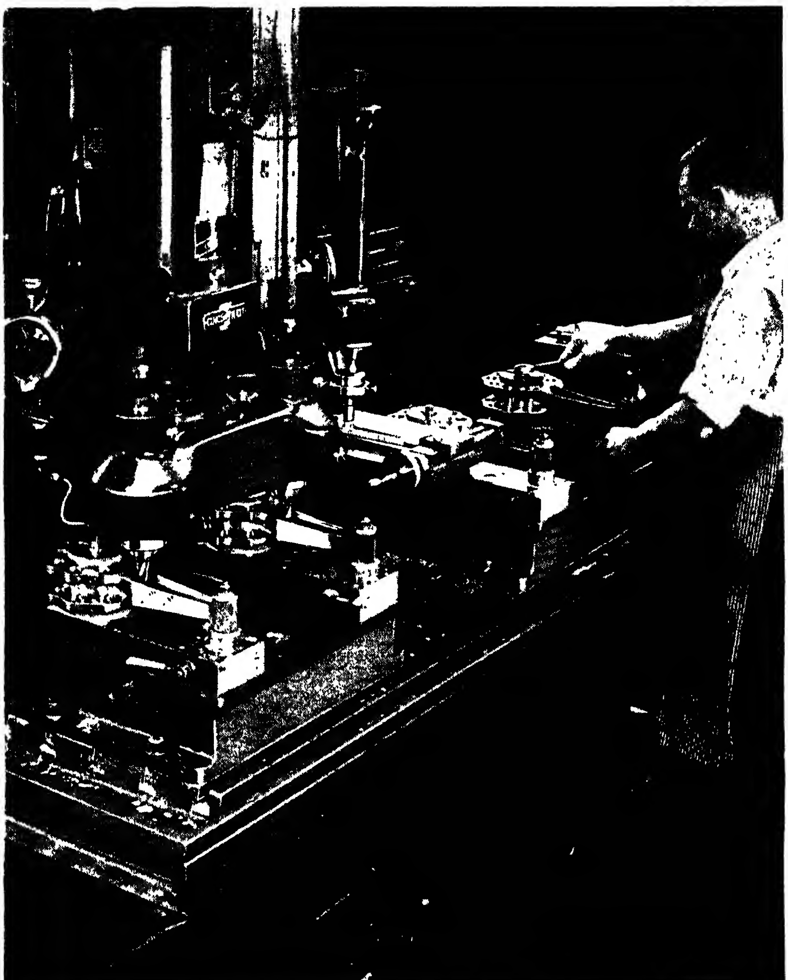

Fig. 5. Milling Machine Tooled up for Milling Channels in Both Sides of Master Rods

an electrical control. The cutters move along one side of the channels from one end of the master rods to the other, and then back along the other side of the channels. Four fixtures are provided on the table, so that two of the fixtures can be loaded while an operation is in process on two rods held in the other two fixtures.

Form Milling Airplane Propeller Hubs.—The milling machine shown in Fig. 6 is employed for removing excess stock from the external surfaces that join the barrels of

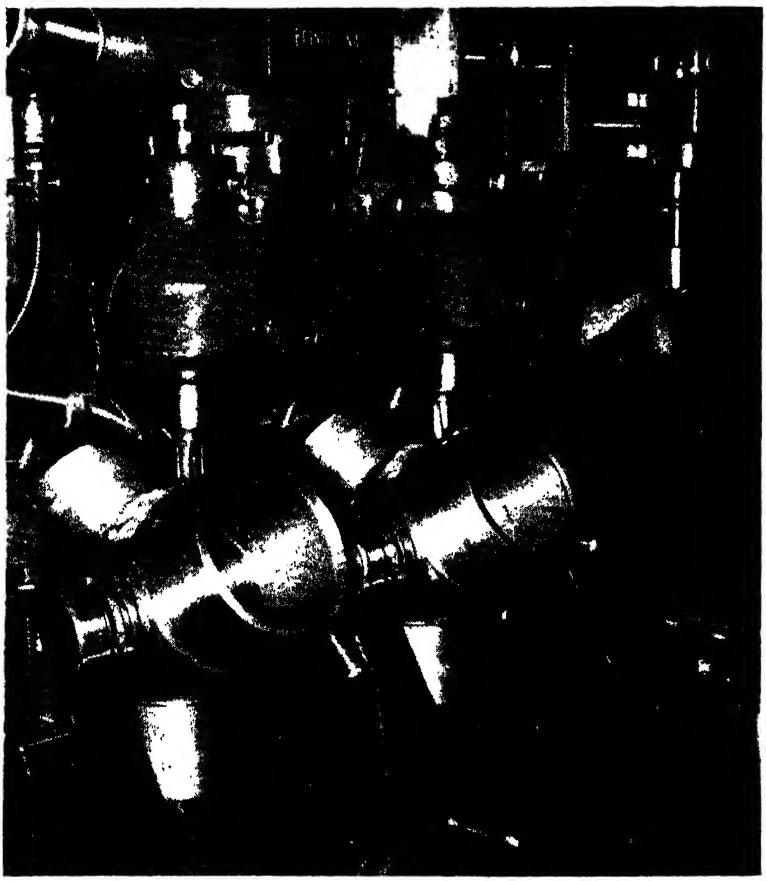

Fig. 6. Milling Machine Removing the Excess Stock between the Barrels of Airplane Propeller Hub Forgings

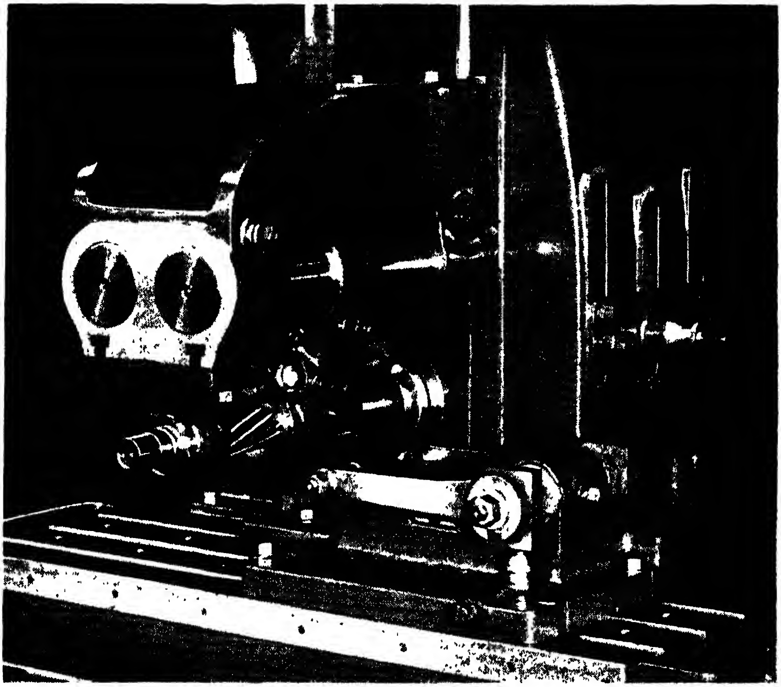

Fig. 7. Milling Operation on Connecting-rods in which the Cutter-head Rises as the Work is Fed past the Cutters

airplane propeller hubs. Two propeller hubs are placed in the fixture at one time, and routing cutters are guided over the contour to be machined under the control of a tracer which rides on a master mounted on the right-hand end of the table. This tracer is operated in two planes, vertical and horizontal, and imparts similar movements to the two cutters. The propeller hubs are mounted on arbors, and are located by a plug on a bar at the rear of the fixture. By indexing the hubs, the excess stock can be milled from between all three barrels.

Master Cam for Controlling Movements of Cutter Spindle.—Master and articulated connecting-rods for airplane engines are milled along the sides two at a time by the machine shown in Fig. 7. The surfaces milled are tapered and rise

on a generous curve at one end. In order to mill this changing contour accurately, the milling head is made to rise vertically in the housing of the machine as the connecting-rods are fed past the cutters.

This rising action of the spindle head is controlled by a master cam on the rear side of the table, which is engaged by a roller on the spindle head, in conjunction with a hydraulic cylinder and pump at the rear of the machine. The hydraulic equipment can be disconnected and the arbor support for the cutter-spindle removed when the machine is to be used for standard milling operations.

Double-spindle Machine having Adjustable Control Cams.—An unusual milling operation is involved in finishing the bolt lugs on the barrel halves for propellers. This operation is performed on the machine shown in Fig. 8, which is

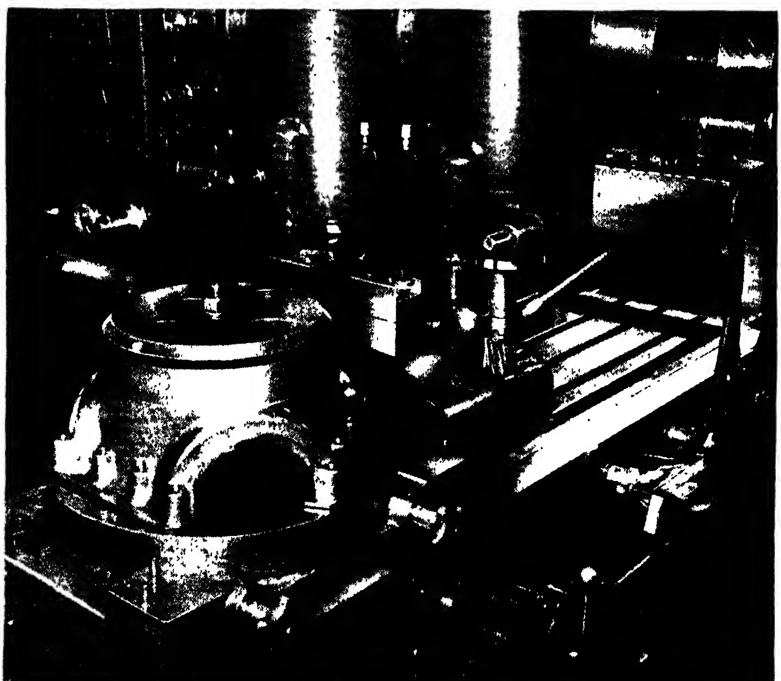

Fig. 8. Milling Machine with Cam-actuated Tool-heads, which is Employed for Milling Twelve Bolt Lugs on Propeller Barrel Halves

equipped with two vertical milling heads. These heads are fed sidewise on an over-arm, each head milling two bolt lugs at different distances from the center of the forging when the work is fed to the cutters. The sidewise feeding movement is accomplished by hexagonal-head studs that project downward from the tool-heads and engage two adjustable cams mounted on a base in front of the work fixture. When the table returns to the front of the machine for indexing the work fixture, the tool-heads are again pulled into their starting positions by two air cylinders. As two bolt lugs are milled by each cutter with every feeding movement of the table, the twelve bolt lugs are milled in three indexings of the work.

Machine Equipped with Templet and Cam Control Mechanism.— Various aircraft shops have developed meth-

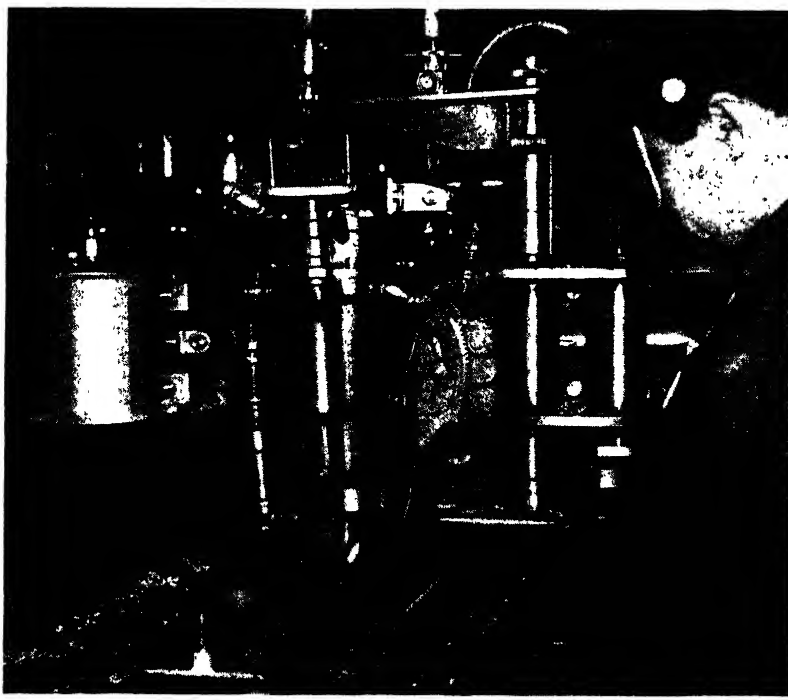

Fig. 9. Planer Type Milling Machine with Two Heads for the High-speed Milling of Extruded Shapes to Irregular Contours

ods for the high-speed milling of extruded sections of aluminum alloy. In Fig. 9 is shown a planer type of machine which is equipped with high-speed milling heads on both sides of the cross-rail. These heads can be fed in and out by pneumatically actuated cams to obtain various contours on the extruded shapes, and also up and down in accordance with templets attached to the front and back of the table. The heads are provided with rollers that ride on top of the templets, the rollers being held in close contact with the templets by air pressure. Right- and left-hand parts can be machined at the same time by the use of the two milling heads, one cutter performing climb-milling and the other conventional milling. The table can be fed in either direction.

The table is operated at speeds up to 25 feet a minute, being driven through chains by a variable-speed drive. Both cutter-heads are driven by separate 15-H.P. motors, the motor shaft in each instance being attached directly to the cutter-arbor. Speeds as high as 10,800 R.P.M. are used with the largest cutters, which are 1 3/4-inch diameter end-mills. Cuts as deep as 0.180 inch are taken the full length of the end-mills.

The cutter-heads can be swiveled for taking angular cuts in combination with concave and convex cuts obtained through the cams and templets. Any length of extruded section, such as used for the cap strips of wings, can be handled. The long extruded sections are held securely to the table by a series of twenty-eight air cylinders, which actuate individual bar type clamps that push the work against stops on the table.

Milling Aircraft Engine Cams.—Cams for aircraft engines are milled completely around their contour by the use of the vertical milling machine shown in Fig. 10. The same equipment is employed for rough-milling the contours on the large end of master rods, such as seen on the table in the foreground.

This milling machine is equipped with a 16-inch circular milling attachment on the knee instead of the regular saddle and table. The circular milling attachment is provided

with upper and lower slides. The upper slide is adjustable by turning the hand-wheel on the regular cross-adjusting screw. Two air cylinders hold a cam mounted on the upper unit against a cam follower on the lower slide, so that as the table rotates, the cam and follower cause it to move in and out. In this way, the contour of the master cam is reproduced on the work.

In the operation on the master rods, stock to a depth of 3/16 inch is removed by a helical milling cutter 1 1/2 inches in diameter by 3 inches long, which extends across both flanges of the master rod. Three rods are rough-milled per hour.

Contour Controlled by Master Cam which Rotates with Work. — The machine shown in Fig. 11 is designed for milling surfaces of irregular contours as the cutter moves

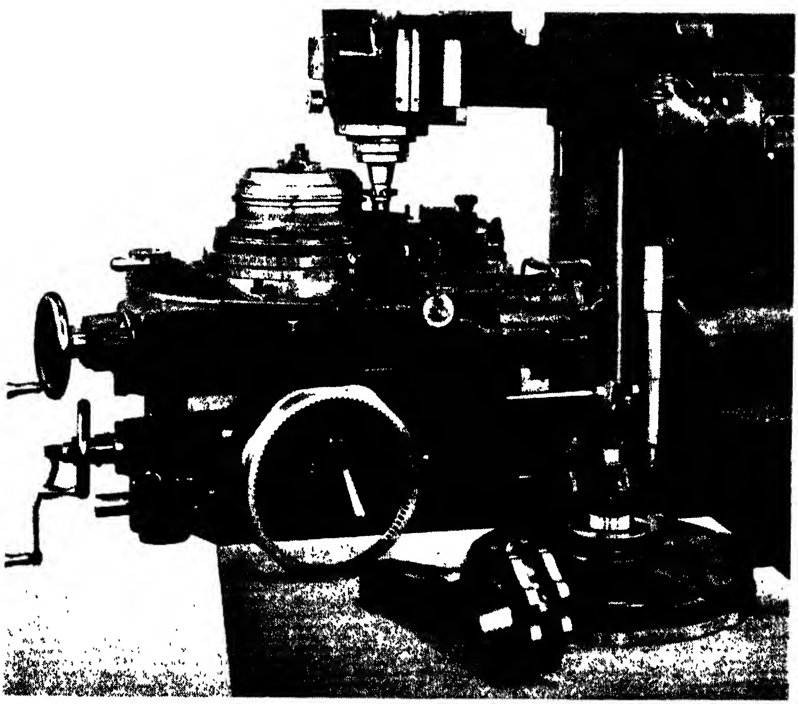

Fig. 10. Vertical Milling Machine Employed for Milling Airplane Engine Cams and Master Rods

around the work under the control of a cam. The particular operation shown consists of form-milling one end of a gun body around a true circle for 270 degrees, and cutting a slight relief toward the center of the part at each end of the circular portion. This necessitates that the cutter be fed radially outward a slight amount after the cut has been started, and radially inward the same amount as the end of the cut is reached.

The cutter movements are derived from a cam of the required contour, which is mounted on the work-head and revolves with the work. Through the action of a hydraulic cylinder at the front of the machine, which exerts constant

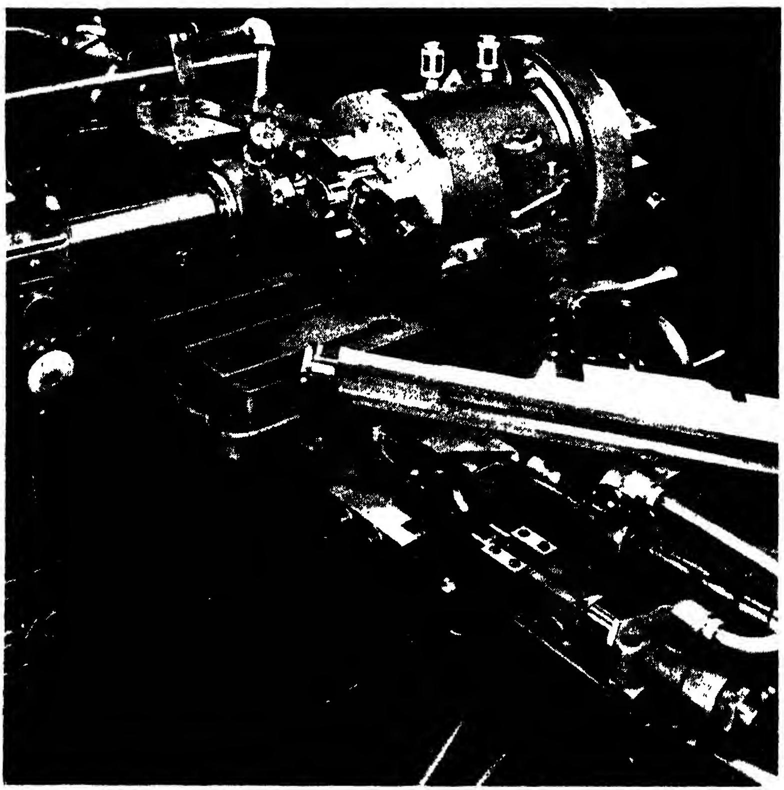

Fig. 11. Work is Moved in and out in Relation to the Cutter by a Cam Action, Both Cam and Work Revolving

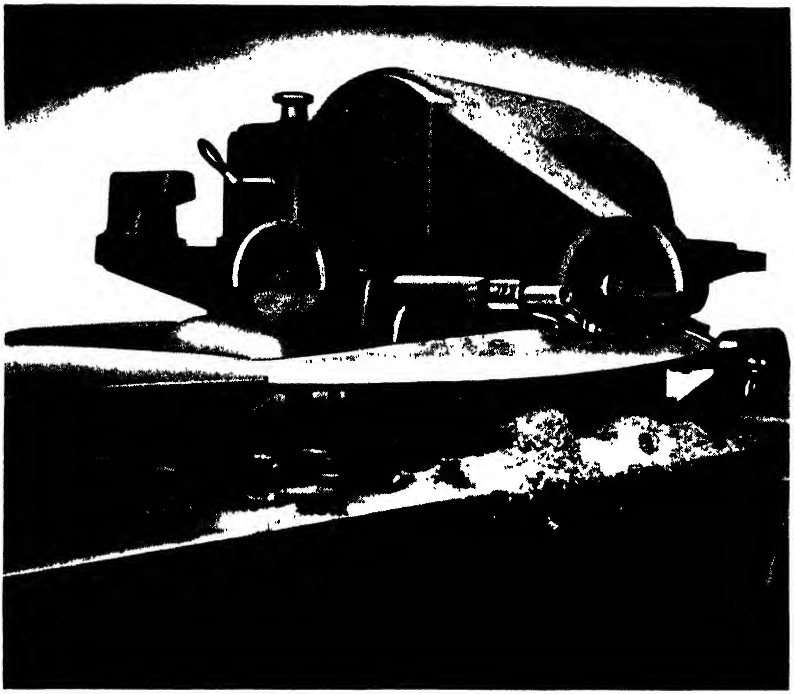

Fig. 12. Equipment Employed in Profile Milling Both the Flat and Cambered Surfaces of Propeller Blades

pressure against the table on which the work-head is mounted, this cam is held in contact with a roller mounted on a unit at the back of the machine. The same unit is provided with a bearing that supports the overhanging end of the cutter-spindle. Thus, as the changing contour of the cam revolves over the roller, the work-table slides forward and backward on the machine bed an amount corresponding to the rise and fall of the cam. The gun body is almost completely enclosed by the special work-head, into which it is inserted from the right-hand end. After the work has been gripped by the chuck jaws, an ingenious lever arrangement is operated to engage a worm drive for revolving the work.

Milling Airplane Propeller Blades.—This machine, which is shown in Fig. 12, is employed after the hub end of the

blade has been centered and rough-turned. The revolving cutter of this machine passes back and forth over the face of the blade while the table is fed longitudinally past the cutter. The profile of the blade is controlled by means of a rotating cam which revolves once for each complete traverse of the table. This cam causes the milling cutter to be moved up and down in accordance with the desired profile, the cam having been developed from a master propeller blade of the desired shape. The cutter is of the inserted-blade type, and is 8 inches in diameter. It runs at a surface speed of 5500 feet per minute, while the blade moves longitudinally at the rate of 3 inches per minute. One side of the blade is flat, and this is milled first in order to provide an accurate locating surface for use in machining the cambered profile of the opposite side.

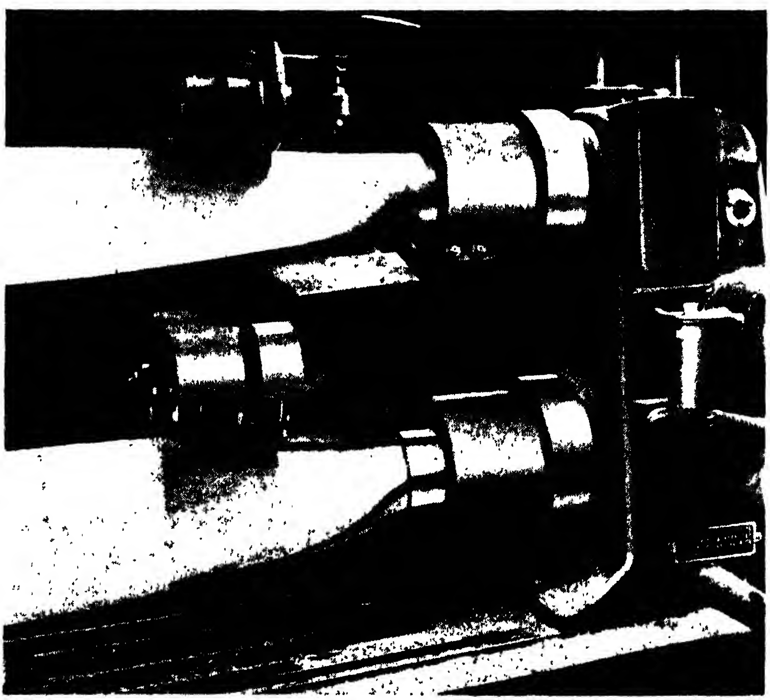

Fig. 13. Profile Milling the Root End of Propeller Blades in a Machine Equipped with a Master Blade for Controlling the Cutter Movements

After the blade has been milled as far as the root section, it is passed to the machine shown in Fig. 13 for profiling the remainder of the blade to the hub end. A master blade is located on this machine above the work, and a roller that follows the contour of the master blade controls the movements of the revolving cutter beneath. The blade and master revolve synchronously, and the carriage on which the cutter and follower are mounted is free to move in a vertical direction. Both roughing and finishing cuts are taken on this machine. The next operation on the blade consists of milling the edges.

Milling Edges of Airplane Propellers.— Propeller blades in an airplane shop are being milled on the trailing and leading edges simultaneously by the machine illustrated in Fig. 14. The fixture of this machine is designed to accom-

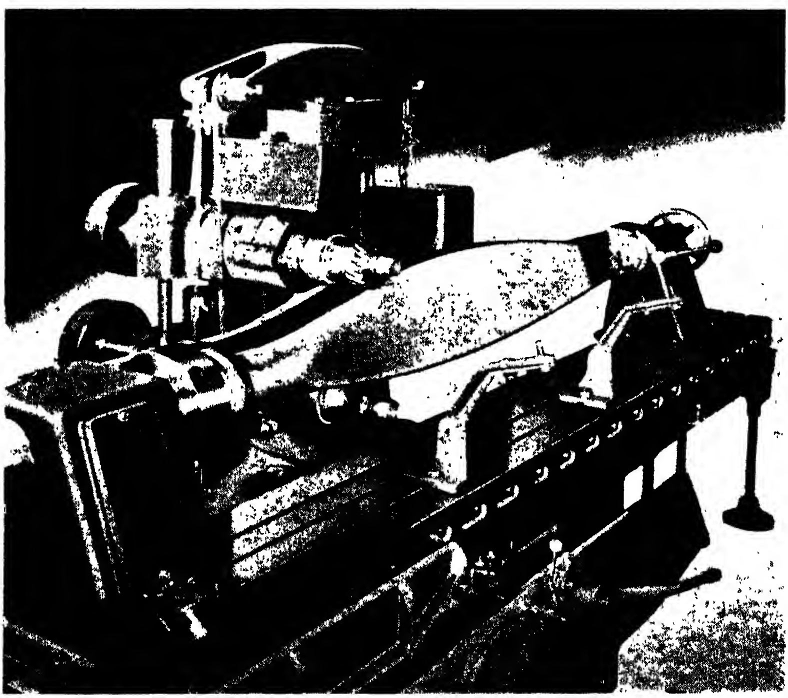

Fig. 14. Simultaneously Milling Trailing and Leading Edges of Airplane Propeller Blade to Desired Profile and Pitch

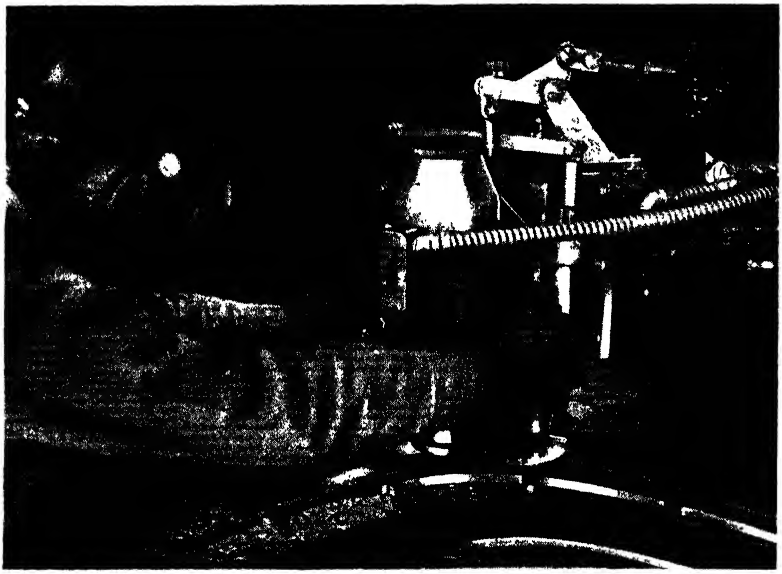

Fig. 15. Routing Machines Operated at Speeds up to 15,000 R.P.M. in Cutting Stacks of Sheets to Irregular Templets

Fig. 16. Employing a Standard Wood Shaper for the Fast Finishing of Aluminum Pieces to Required Profiles

modate propeller blades of various lengths and pitches. A removable profile cam located behind the work is bolted to both the headstock and the tailstock, while a pitch cam is mounted on the front of the saddle for generating varying pitches on the blades by swiveling the blade as it is fed past the cutters. Rollers mounted on the cutter-arbors contact with the top and bottom of the profile cam, thus raising and lowering the cutters as they follow the edges of the blade. This cam is so designed that at the beginning and end of the cut the two cutter-heads are spread apart sufficiently to facilitate loading and unloading of the work.

High-speed Routing Operation.—Routing operations, such as the one illustrated in Fig. 15, are performed at high speed, the routing spindles being driven at from 10,800 to 15,000 R.P.M. by direct attachment to motor armatures. Generally, ten sheets of material, stacked to obtain a height of about 1 inch, are routed at feeds up to 18 feet per minute. A typical operation of this sort is shown. The routing heads are mounted at the outer end of hinged radial arms, 7 feet long. A single-lip cutter, of 5/16 inch diameter, is guided by a roller above the tool which rides along the edge of Masonite templets fastened on top of the sheets. These templets are located as close together as possible in order to hold scrap to a minimum.

Machining Aluminum Parts on Woodworking Machine.—The application of standard woodworking machinery to the machining of aluminum parts is illustrated in Fig. 16, which shows a wood shaper being used to finish aluminum castings according to the outline of fixtures in which they are held. A regular wood-shaper tool bit is mounted on the machine spindle, there being a collar below the tool that is guided along the contour of the combined fixture and templet, so as to produce the same contour on the work. The work is merely "wiped" across the cutter, the latter being run at 11,400 R.P.M.

Routing Aluminum-alloy Sheets on Radial Type Machine.—Following conventional practice in the airplane-building industry, blanks for parts to be formed from sheet-

aluminum alloy are cut by radial routing machines in accordance with templets fastened on top of stacks comprising ten to twelve sheets. Routing has been greatly speeded up in one plant by the provision of the large rotary table seen in Fig. 17, which runs around a routing machine provided with an arm 9 feet long. Four table sections with plywood tops 10 feet long by 4 feet wide provide a means of keeping the routing machine in constant operation, because finished work can be removed from these tables and new stacks of sheets and templets loaded quickly enough so that another stack of sheets can be pushed beneath the routing head as soon as the cutting of one stack has been completed.

The channel track on which the table wheels run is 16 feet in diameter, and the wheels or casters are 7 inches in diam-

Fig. 17. This Machine has a Large Rotary Table with Four Loading Sections for Routing Sheet-metal Blanks

Fig. 18. Routing Machines Used for Cutting Blanks from Stacks of Sheet Metal: Master Templets are Fastened to the Sheets

eter. The table frame is largely built up of welded construction and assembled by bolts. The Shrillo routing head runs at a speed of 12,000 R.P.M.

Routing Stack of Sheets to Shape of Master Templet.—Metal sheets to be formed under the hydraulic presses are first cut to the desired outline by routers of the type illustrated in Fig. 18, which consist of high-speed spindles mounted on the outer ends of swinging hinged arms. The routing spindles are driven by high-cycle electric motors running at 10,800 R.P.M. From six to eight sheets are generally stacked on top of each other on plywood boards laid on the routing table to obtain a total thickness of about 7/16 inch, and templets of Masonite are placed on top of the stacked sheets, as illustrated, and screwed to the plywood board underneath. In this way, a large variety of parts can be routed from the sheets of stock with minimum waste of material.

Above the routing tool is a fixed bushing that is slightly larger in diameter than the tool. This bushing is guided around the templet to cut out the stock to the desired outline, allowance being made on the templet for the fact that the bushing is of greater diameter than the cutter. The routing cutter is 5/16 inch in diameter, and is of the spiral type. The cutters vary in size by increments of 1/64 inch, and guide bushings are provided to suit.

Milling Operations on Machines which Automatically Reproduce Shape of Master Templet. — The teeth on sprockets are machined complete from circular rims on the machine illustrated in Fig. 19. Two sprockets are mounted on the vertical table for simultaneous machining by a spiral milling cutter about 1 1/2 inches in diameter by 6 inches long. The cutter moves automatically, in and out and up and down, around the sprocket, as controlled by the movements of a tracer around the steel templet mounted above the work-pieces. On some sprockets, the teeth are completely machined in one cut, while two cuts are taken on others. The sprockets seen on the machine are 30 inches outside diameter, and have fourteen teeth approximately 1 1/2 inches high.

The teeth on sprockets may be flame-cut over-size to the desired outline before they are brought to the Kellermatic. so that only a comparatively light cut need be taken by that machine.

The machine shown in Fig. 20 is used for finishing the contours of cam forgings such as the one seen lying at the front end of the table. Two roughing and two finishing cuts are taken on each forging, the size of the tracer being

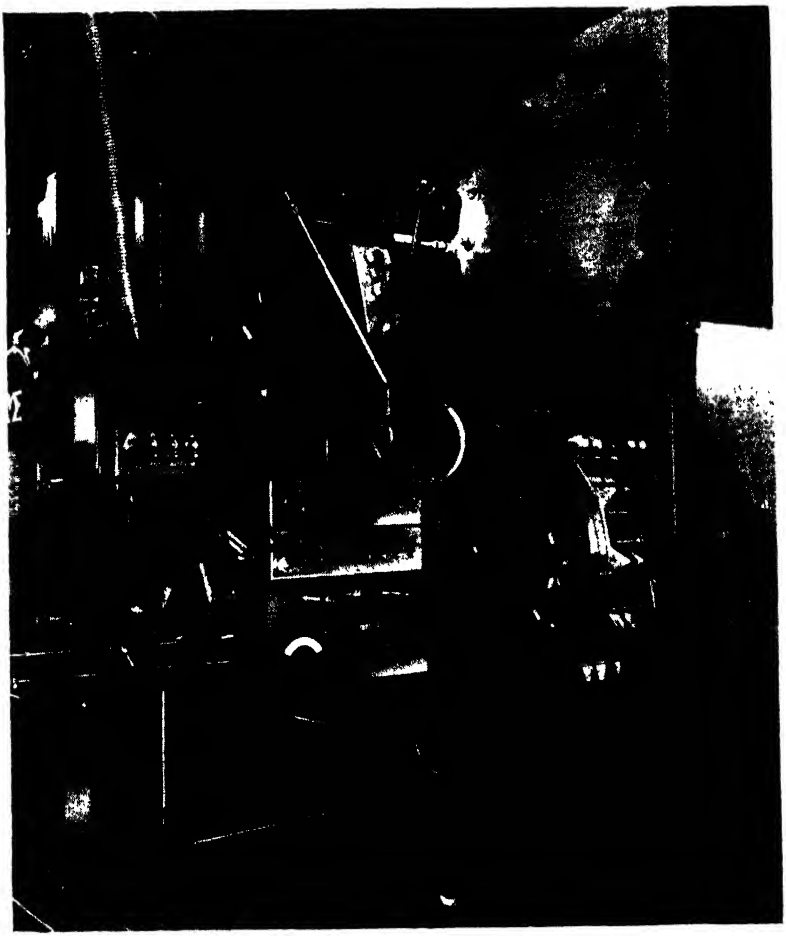

Fig. 19. Simultaneously Machining the Teeth of Two Sprockets on Machine which Automatically Reproduces Shapes of Master Templet

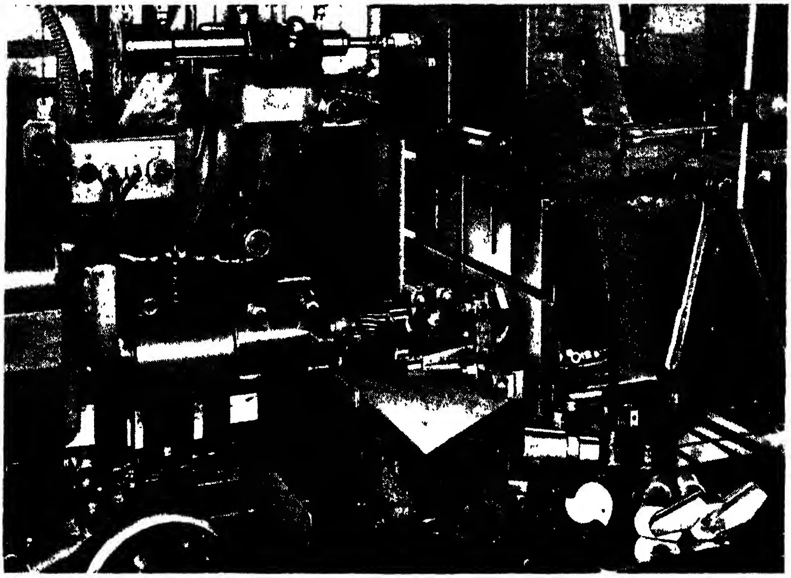

Fig. 20. Accurate Machining of Cams

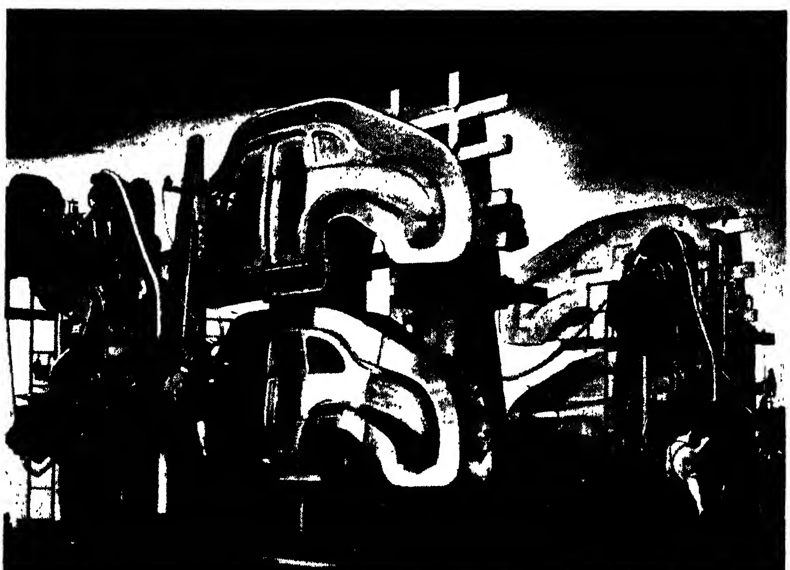

Fig. 21. Producing Automobile Body Dies

changed for the successive cuts. Dimensions are held within 0.002 or 0.003 inch. The piece produced in the particular set-up shown has two distinct cam surfaces finished in one set-up. Cuts are taken both in the conventional manner and on the climb cut principle.

Automatic tool-room machines for machining large automobile body dies from wooden models are illustrated in Fig. 21. As a stylus or tracer on an upright follows the contours of the model at the top of the work-supporting uprights, a milling cutter is automatically moved along a similar path on the die being machined.

Profile Milling Machine with Horizontal and Vertical Spindles.—In Fig. 22 is shown a profile milling machine designed for handling extruded aluminum alloy stock, such as is used for main airplane beams, up to 30 feet in length. Profile milling cuts can be taken in both vertical and horizontal planes, as the machine is equipped with three cutter-heads, one of which has a horizontal spindle, and the other two vertical spindles. These cutter-heads are mounted on a carriage which is fed along the stationary work-table. The operator ordinarily stands on a platform attached to the rear of the carriage as it moves back and forth, but the machine can also be started and stopped from the front.

One of the features that aids in obtaining high production is the provision of twenty-six air-operated clamps for gripping the long pieces of material. Clamping and unclamping are instantly effected by depressing push-buttons which control solenoid switches that actuate the valves of the clamp cylinders. With this equipment, reloading time is greatly reduced. The milling cuts are controlled from templets clamped to the front or back of the table, which have profile edges in either horizontal or vertical planes as required. Rollers mounted on the cutter-heads ride along these profile or cam bars and cause the heads to move in and out, or up and down, in accordance with changes in the profile. The rollers are held in contact with the cam bars by air pressure. A close-up view of the horizontal-spindle head is shown in Fig. 23, and a view of the vertical-spindle heads is seen in Fig. 24.

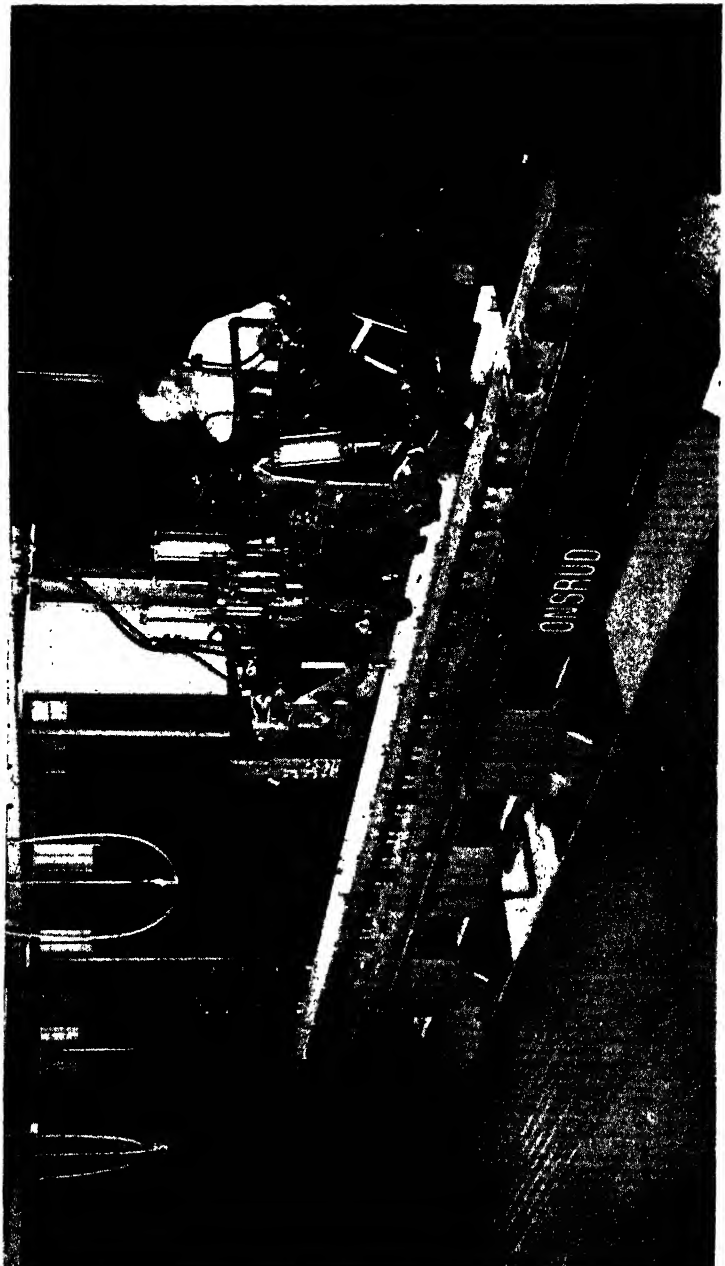

Fig. 22. Profile Milling Machine Equipped with Two Vertical-spindle Cutter-heads and One Horizontal-spindle Cutter-head for Taking Cuts on Long Main Beams of Airplanes and Similar Parts

During the milling of a main beam or similar part, the feed of the milling heads is automatically changed for deeper or lighter cuts, so as to guard against overloading of the individual driving motors and, at the same time, permit milling to maximum depths. Cuts are taken to a depth of about 3/4 inch. The cutter-spindles are run at speeds up to 10,000 R.P.M. The motors that drive the cutter-spindles receive high-frequency electric current from a bus-bar that is constructed along the top of the machine, as seen in Fig. 22. Although one horizontal-spindle cutter-

Fig. 23 Horizontal Cutter-spindle on the Profile Milling Machine Shown in Fig. 22

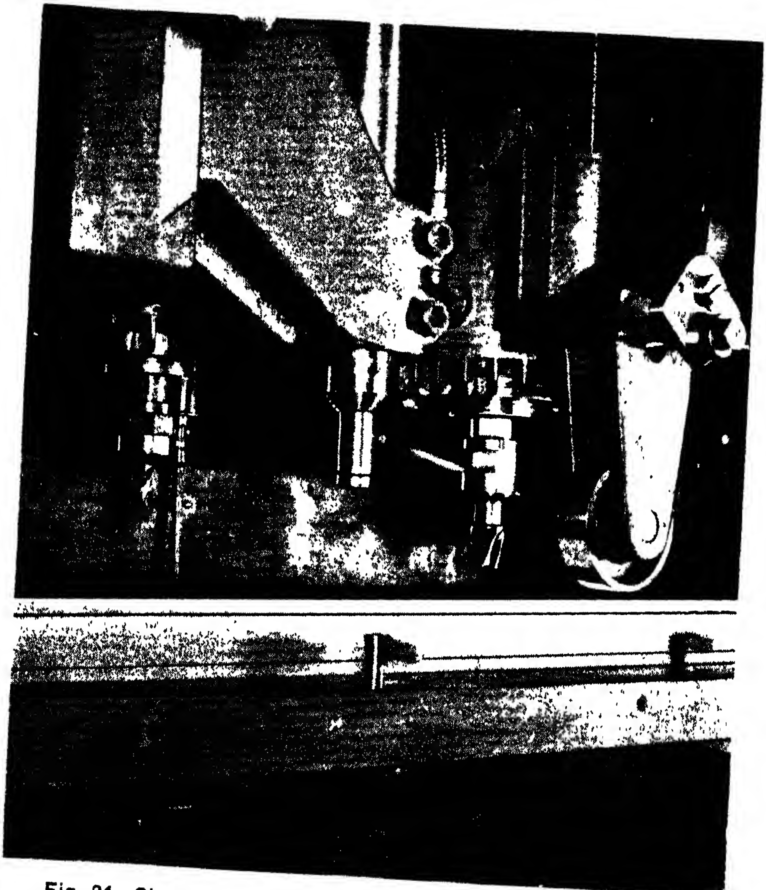

Fig. 24. Close-up View of the Two Vertical Cutter-spindles of the Machine Shown in Fig. 22

head is provided on the right-hand end of the carriage only, provision has been made for mounting a second head of this type at the left-hand end as well. The cutter-heads are driven by 15-H.P. motors.

Broaching with Vertical and Horizontal Machines

The broaching process is utilized in many machine-building plants because it is exceptionally rapid, accurate and leaves a finish of good quality for a cut surface. This process is applied both to internal and external surfaces. While the broaching tools as a general rule are expensive, the process is very efficient in producing large quantities of duplicate parts. This explains why broaching is done so extensively in the automotive and other industries requiring many duplicate parts.

Broaching consists in cutting away metal to obtain a given form, size and finish by using a broach (or several successive broaches in some cases) having a series of teeth which progressively increase in size or height from the starting end, so that each tooth takes a light cut and thus, by a succession of cuts, forms a surface quickly and accurately. Broaching is applied to many different classes of work. A simple example of internal broaching consists in forming a hole of square, hexagon, or other form from a drilled hole. Originally, broaching was restricted to internal work of this kind and to the cutting of keyways; but now many flat or other external surfaces are machined by this process.

The general function of a broaching machine is to supply the power required for broaching and provide whatever stroke and speed adjustments may be needed. The machine must also be equipped with a suitable work-holding fixture and with means of supplying a cutting fluid to the broach. Hydraulically operated broaching machines are widely used at the present time because they provide a smooth applica-

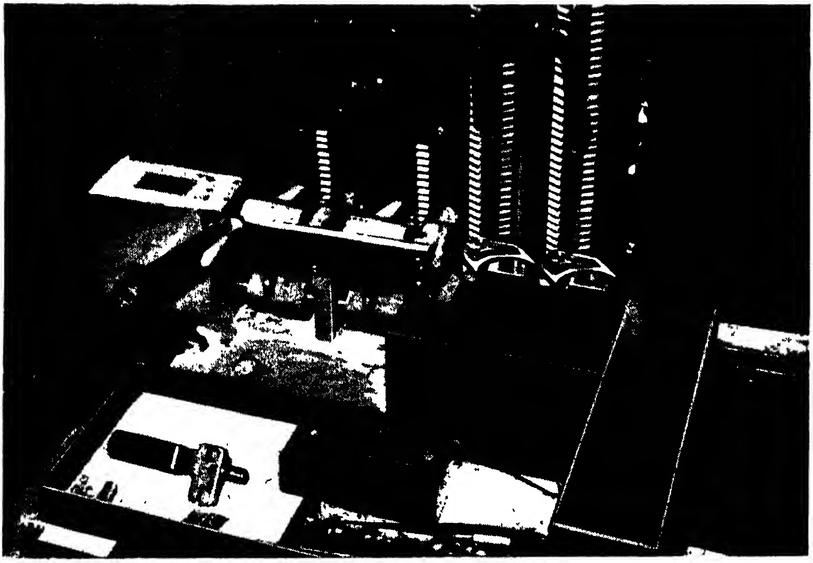

Fig. 1. Broaching Gear Shifter Shoes for Automobile Transmissions

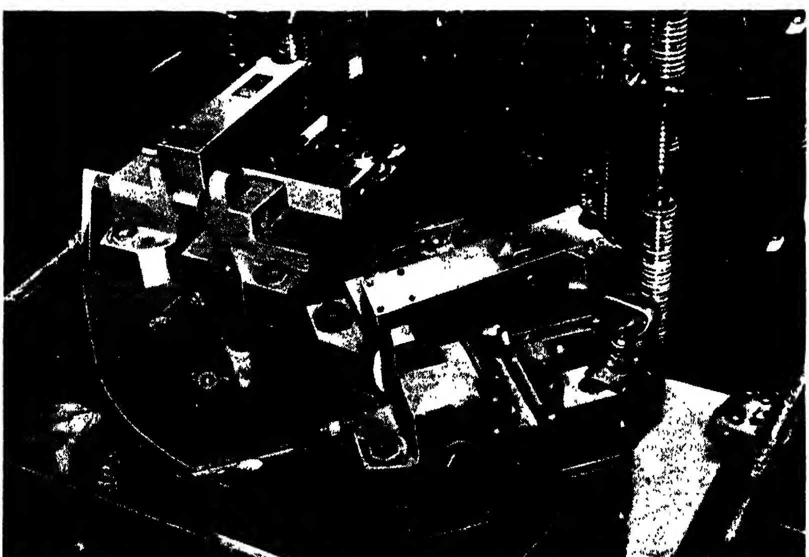

Fig. 2. Other Broaching Tools and Fixtures for Gear Shifter Shoes

tion of power and flexible control. The machine may be either vertical or horizontal in design.

Broaching Gear-shifter Shoes and Levers.—An interesting example of surface broaching consists in machining the gear-shifter shoes and shifter levers of automobile transmissions. It would be almost impossible to produce the contours required on these parts by other methods without resorting to a multiplicity of set-ups. The final and most important operation on the first and reverse shifter shoes for a certain transmission, prior to heat-treatment, is the broaching of the shifter slot and two adjacent pads. These cuts are all taken by a vertical broaching machine equipped, as shown in Fig. 1, with a four-station work-holding fixture. The illustration shows the shifter slot being broached in two pieces held in the left-hand side of the fixture at the same time that two pads are being finished on parts held in a different position in the right-hand side of the fixture.

In broaching the second- and third-speed shifter shoe, a part circle is finished in the shifter-pad throat, and two bosses are finished at the same time. The fixtures shown in Fig. 2 were designed for holding two shoes at a time in such a manner that practically a half circle is presented to a circular broach. Consequently, one pass of the broach produces the desired circular form on the two shoes. At the same time, broaches to the right and left of the circular broach finish bosses on one side of each part. Two pieces are thus completed with each cycle of each ram, duplicate broaches and fixtures being provided on the two sides of the machine.

Broaching Crankshaft Bearing Caps.—Crankshaft bearing caps are broached on the machines shown in Figs. 3 and 4. These caps are cast and machined in one piece in order to reduce handling and eliminate a considerable number of time-consuming operations. The dual-ram hydraulic broaching machine is equipped with fixtures that swivel automatically into line with the broaches prior to each downward movement of the ram and into the loading position before each return stroke. The castings are first

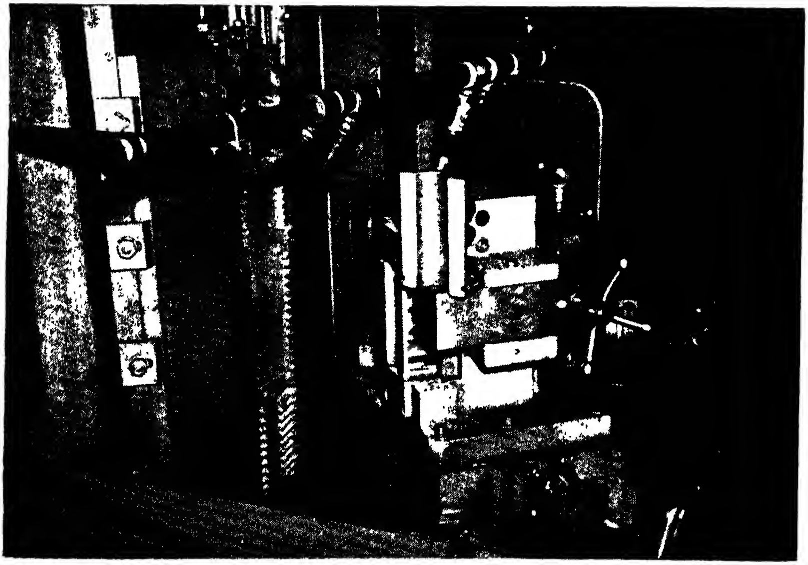

Fig. 3. Broaching Main Bearing Caps, which are Cast in One Piece for an Entire Engine Block

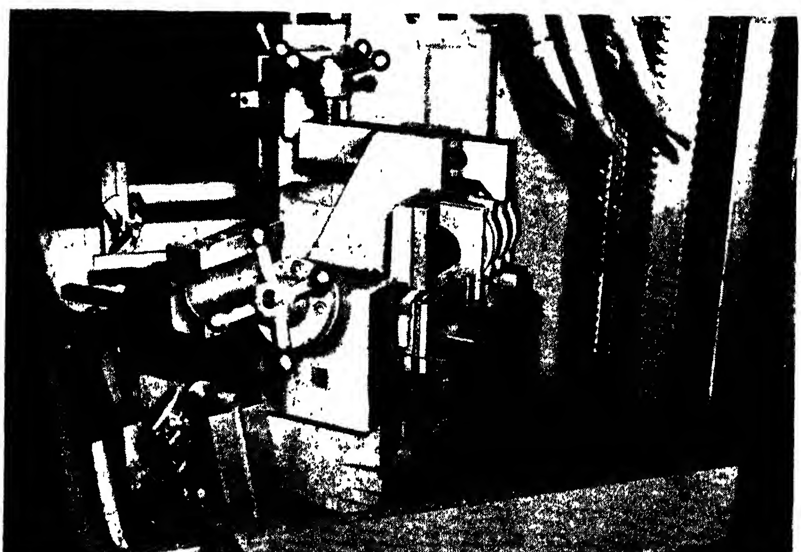

Fig. 4. Two-station Fixture on Right-hand Side of Machine Shown in Fig. 3

loaded, one at a time, into the left-hand fixture, as seen in Fig. 3, for broaching the long contact faces and the narrow flat edges that extend the full length of the casting at right angles to the contact faces. The castings are then transferred to the right-hand fixture, shown in Fig. 4, which is equipped with two stations, into which the castings are successively loaded. While in the right-hand station, seen in the foreground, narrow grooves are broached down the sides of the casting at right angles to the contact faces. Then, when the casting is transferred to the left-hand station, which is in the background in Fig. 4, broaching is performed on the narrow edge that extends across the top of the casting at one end, parallel to the contact faces. Two broaches are provided on the ram of this station to suit castings for either six- or eight-cylinder engines, but

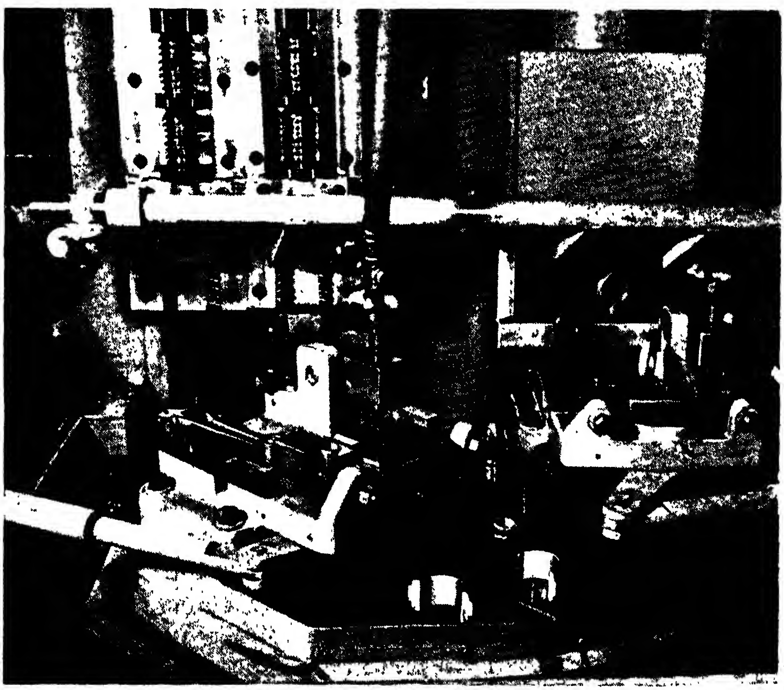

Fig. 5. Connecting-rods and Caps are Broached on the Contact Faces, in the Crankpin Bearing, and on the Sides of the Bolt Lugs

only one broach is used at a time. The production is 120 castings per hour.

Broaching Connecting-rods and Caps. — The dual-ram hydraulically operated vertical broaching machine shown in Fig. 5 is employed for broaching the contact faces or parting line on both the connecting-rods and caps of automobile engines, and also the crankpin bearing surface and the sides of the bolt bosses. Identical cuts are taken on both sides of the machine, each fixture being designed to hold one rod and one cap at a time. The connecting-rod is located from the reamed wrist-pin hole and the previously milled under side of the bolt bosses, while the cap is also located from the milled bolt-boss surfaces.

At the beginning of the operation, two broach sections about 7 inches long rough-broach the contact faces on the rod and cap, and these are followed by ten semicircular sections about 4 inches long which broach the crankpin bearing surface. Along the sides of the last one of these semicircular sections are straight broach sections, also about 4 inches long, which machine the sides of the bolt bosses. Finally, at the top end of each broach is a flat section, about 4 inches long, that takes a shaving cut on each contact face, making these surfaces flat within 0.001 inch. The production is 240 rods and caps per hour.

Another broaching operation on connecting-rods and caps is shown in Fig. 6. These parts are broached across the half-round bearings and their joint faces in a single-slide vertical broaching machine. A second machine of the same type, but provided with a different set of broaches and work fixture, broaches the sides of the bolt bosses on both rods and caps in a preceding operation, and also broaches the tops of the bosses on the rods and their adjacent shoulders.

In the operation illustrated, the production rate is 125 finished rods and caps per hour. The connecting-rod is located in the left-hand side of the fixture by placing the wrist-pin hole over a stub pin, and the previously broached sides and bolt bosses between hardened plates. Two lever-operated jaws are then moved to clamp the rod securely.

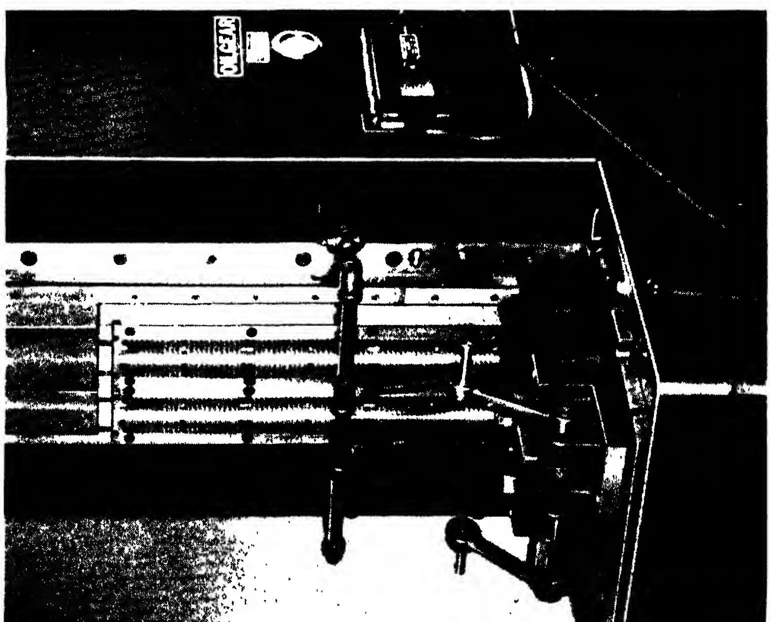

Fig. 6. Broaching Machine Used for Finishing Connecting-rods and Caps

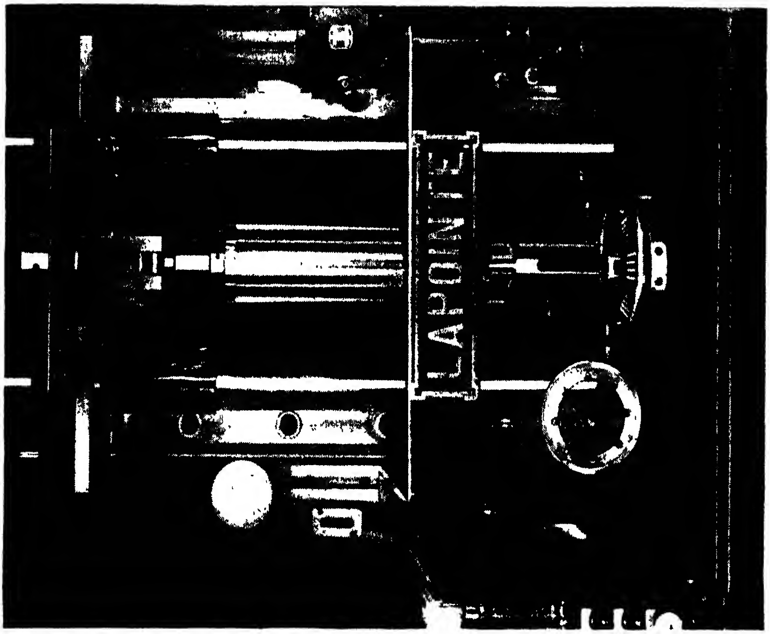

Fig. 7. Machine Employed for Broaching Gear Segments to Form Slots

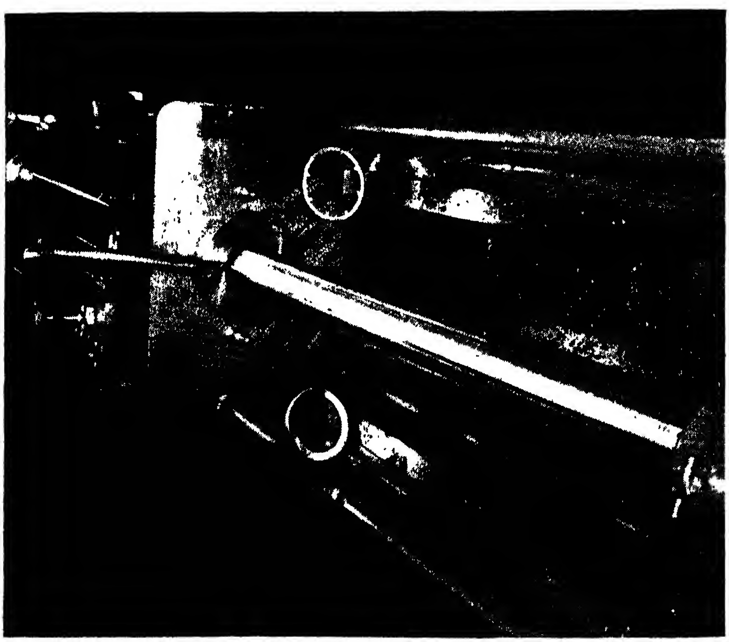

Fig. 8. Broaching Internal Teeth in Rings that are Later Cut up for Use as Rifle Apertures

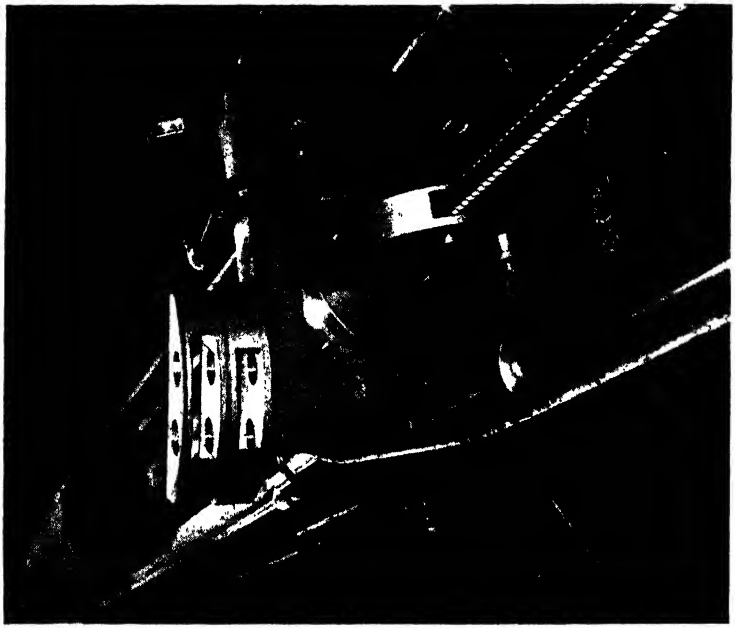

Fig. 9. One of a Series of Five Broaching Operations on the Rectangular Slots of Counterweights

The cap is located between plates on the right-hand half of the fixture, and a lever-operated double cam clamps it securely.

Hydraulic Machine which Pulls Broach Down Through the Work.—The hydraulic broaching machine shown in Fig. 7 is used for cutting away the inner edge of eight holes in gear segments, so as to form slots. This operation is performed in a single pass of the eight-broach tool. A pulling head in the base of the machine pulls the tool downward through the work. In operation, a gear segment is loaded on the fixture, as shown, and the overhead broach slide then moves the broach downward until it connects automatically with the pulling head. As the broach is pulled through the work, it is automatically disconnected from the upper slide, so as to permit the work to be removed from the table when the operation is completed. At the end of the operation, the pull-head raises the broach until it is again connected with the upper slide, after which this slide withdraws the broach through the fixture, and it is automatically disconnected from the pull-head to permit loading. Engineering specifications necessitate that these slots be produced within a tolerance of 0.0005 inch. The equipment used not only meets this requirement, but does so in minimum production time.

Internal Ring-broaching Operation. — The horizontal broaching machine shown in Fig. 8 is used for broaching eight rifle apertures in a ring that is later cut up into segments. On the left-hand way of the bed is seen a ring as it appears before the operation, and on the right-hand way one of the broached rings. Stock to a depth of 1/4 inch is removed with one stroke of the 4-foot broach, the diameter of the hole at the beginning of the operation being 3 1/2 inches. These rings are ground on both faces before coming to the broaching operation, so as to insure accurate seating in the work fixture of the broaching machine. The tolerance allowed on all surfaces of these parts is 0.002 inch. This machine is also used for broaching a variety of other parts. It operates at a hydraulic pressure of approximately 1000 pounds per square inch.

Broaching a Slot in a Counterweight. — The horizontal type of machine shown in Fig. 9 machines the rectangular slots that extend through counterweights. Lying on top of the machine are two of these counterweights, the bottom one showing the appearance of the slot before any broaching is performed, and the top counterweight the appearance of the slot at the end of the broaching.

The particular operation illustrated consists of rough-broaching the rectangular slot at the top and bottom in two steps, the counterweight being located on the fixture by a cylindrical plug that passes through one of the reamed pin-holes in the counterweight and through a bushing in an arm of the fixture.

All together, five broaching cuts are taken on the counterweights by this machine. After the excess stock at the top and bottom of the slot has been broached out with the equipment shown on a lot of parts, the broach is changed for another, which machines the two ends and both sides of the slot in one pass. Then a third broach is substituted, which cuts a relief simultaneously on both sides of the slot for a length of approximately 6 inches. Finally, this broach is again changed for one that finishes both ends of the slot in one pass. The slot in the particular counterweight handled by the equipment illustrated must have an over-all length between 8.362 and 8.366 inches, similar tolerances being specified for the slot widths.

Broaching Connecting-rods on Duplex Type of Machine.— Articulated airplane engine connecting-rods are broached completely over all outside surfaces, with the exception of the channels, by the dual-ram upright broaching machine illustrated in Fig. 10. The channel sides and the boss faces are first broached in this machine with different tooling from that shown. Then, after a lot of rods has gone through these operations, the broaches and fixtures shown are substituted on the machine.

The tooling on the left-hand side of the machine is employed for broaching one flat arm surface on one rod at a time, the rods being reversed in the fixture for broaching the opposite flat sides. The connecting-rods are then placed

endwise in the two stations of the right-hand fixture for broaching the round boss ends, the rods being also reversed in this fixture for broaching both ends. Only enough stock is left on the connecting-rods for grinding purposes.

The fixtures are loaded at the front of the table, and are automatically moved into the broaching positions while the broaches are at the top end of their strokes. At the end of the working strokes, the fixtures are again moved into the reloading positions before the broaches come up. When one of the broach slides is going down the other is rising, thus enabling the fixture at the left to be loaded while work in the right-hand fixture is being broached, and vice versa. The back and forth movements of the fixtures on the table are effected by hydraulic means, and the broach rams are

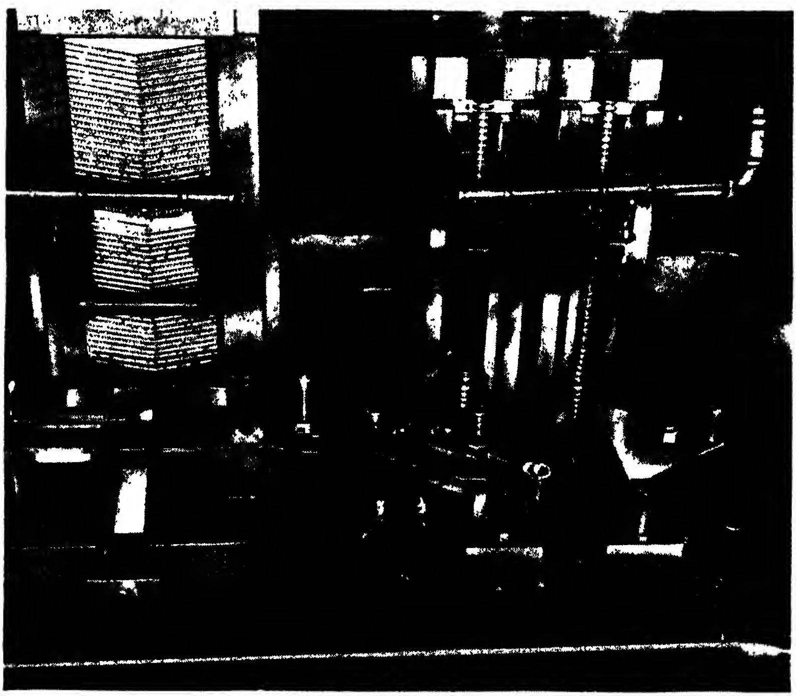

Fig. 10. Broaching Machine Used for the First Machining Operations on Outside Surfaces of Articulated Connecting-rods

Fig. 11. Broaching Serrations One at a Time in Tractor Sprockets, by Indexing the Work

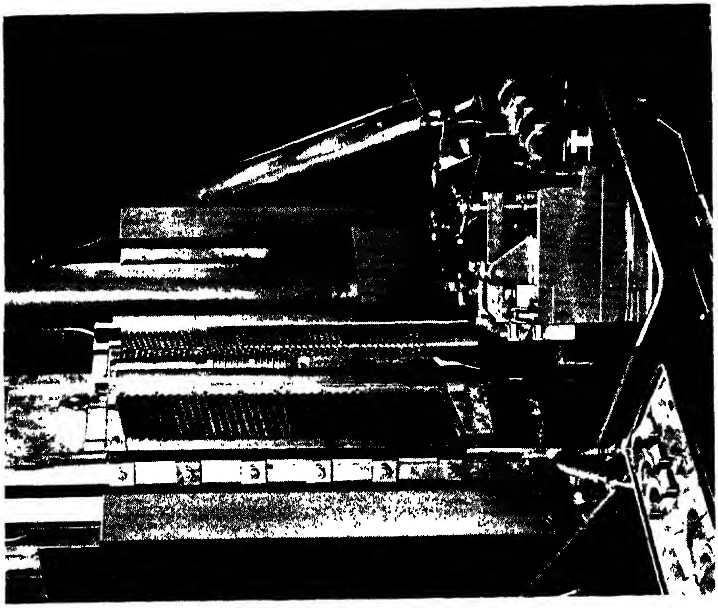

Fig. 12. Broaches and Fixtures Designed for the Simultaneous Machining of Various Surfaces on Crankshaft Bearing Caps

also actuated hydraulically. An overhead hoist and track enable the broaches and fixtures to be changed easily.

Indexing Work for Broaching Equally-spaced Serrations.—Tapered serrations in tractor sprockets are formed on the broaching machine shown in Fig. 11. In this operation, only one serration is broached at a time, but it is cut to its full depth with a single stroke of the ram, the ram being pulled through the work from below. At the end of the down stroke, the table moves the sprocket a slight amount toward the back of the machine, so that the broach will clear the work on the up stroke. During the up stroke, the work is indexed a distance of one serration and is then fed forward again, into position for the next down stroke. The machine stops automatically at the end of the operation. The sprocket, like the hub, is held in a tilted position because of the tapered surface on which the serrations are machined. The sprockets are steel castings.

Broaching Cylinder Block Bearing Caps.—The application of the broaching process to the finishing of metal parts frequently calls for ingenuity in designing both the broaches and the work-holding fixtures. Fig. 12 shows a broaching machine used for finishing cylinder-block bearing caps in a truck engine plant. Two caps are mounted in the two stations of each fixture, the work in one of the fixtures being reloaded during the broaching of the parts in the other fixture. Identical broaching tools are provided on both rams of the machine.

The bearing caps in the first station are broached on the sides at the same time that caps in the second station are broached on the half-hole or bore, on the contact faces, and on the ends. The fixtures are swung parallel with the broaches for the operation and away from the broaches for reloading.

Broaching Sprocket Teeth.—In a plant making tractors, the sprocket wheels which drive tractor shoe tracks or caterpillar treads are cut from tough steel plate four at a time by employing a multiple torch oxy-acetylene cutting equipment. The sprockets are cut out completely both along

their external and internal contours. Four torches are automatically guided over the plate as a tracer follows around a templet of the required contour. Although smooth surfaces are obtained by this method of cutting the sprockets, specifications require that the sprocket teeth be broached around their contact surfaces. This operation is performed by means of the vertical hydraulic broaching machine shown in Fig. 13. Two sprockets are broached at a time. They are clamped on the fixture by means of a heavy head which is lifted to and from the work through the use of

Fig. 13. The Contact Portions of Sprocket Teeth are Broached on a Machine Equipped with an Indexing and Sliding Fixture, Hydraulically Operated

an overhead hoist. The heavy top casting guards against the possibility of the sprockets raising during the taking of the cuts. The broaching fixture is mounted on a slide which moves forward to clear the broach sections on their return stroke toward the top of the machine. Then the fixture indexes to bring the next tooth of the sprockets into position for the broaching operation, after which the fixture slides toward the machine column to properly position the sprockets for the next downward stroke of the broaching ram. Stock is removed for a length of about 1 1/2 inches

Fig. 14. Broaching Operation Employed in Finishing Slots that Extend the Full Length of the Base on Gun Sleighs

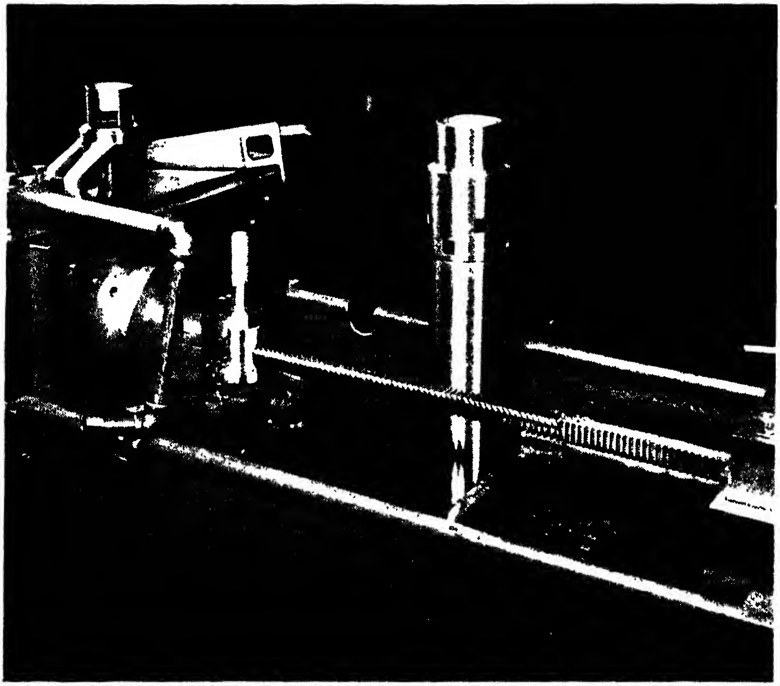

Fig. 15. Broaching Equipment Employed for Cutting Square Openings within Close Tolerances in Several Landing Gear Parts

on each side of the sprocket teeth. When the fixture has been indexed twelve times, as required for broaching thirteen teeth, the operation stops automatically.

Slot Broaching Operation.—Accurate slots are broached on opposite sides of the sleigh for 75-millimeter guns with the horizontal broaching machine illustrated in Fig. 14. One of the finished pieces is seen lying on top of the machine. The part is loaded in the broaching fixture with the side to be broached pointing downward. The slots are approximately 26 inches long. The width across both slots must be held to size within plus or minus 0.002 inch while the height of the slots must be held within plus or minus 0.001 inch. The sleigh is a built-up member obtained by welding a tubular piece to a steel forging.

Broaching Holes in Landing Gear Parts.—The particular operation illustrated by Fig. 15 consists of broaching four holes through a landing gear truck. Holes are drilled through the part in the desired position preliminary to the broaching operation, and these holes are shaped to square openings as the broach is pulled through them, two holes being broached simultaneously. In the case of the truck, the holes must be 0.814 inch square within limits of plus 0.001 inch, minus nothing. The distance from the top of the holes to the end of the piece must be held within plus 0.002 inch minus nothing.

In the truck broaching operation, the work-piece is located radially from ground surfaces. The fixture is made with two wings that extend outward at angles of 45 degrees, and the part is located first with one ground surface against one wing for broaching two holes, and then with the second ground surface against the other wing for broaching the remaining two holes. A plug with holes that provide clearance for the broach is inserted vertically in the landing gear truck, as shown, so as to provide adequate support for the thin wall of the part during the operation. The work-piece is located for height by a shelf on the fixture.

The right-hand end of the broach is supported on a carriage, from which it is automatically disconnected to allow the broach to be drawn through the work. On top of the fixture housing is seen one of the broached landing gear trucks and also a motor mount bracket in which a hole is similarly machined.

Eight holes are broached through piston walls, as indicated by the piston standing on the bed of the broaching machine in Fig. 15. This operation on the pistons is performed in a similar manner to the one illustrated. Four settings of the piston are required to broach the eight holes.

Combined Helical and Straight Broaching.—The horizontal broaching machine illustrated in Fig. 16 performs a combined helical and straight broaching operation on Diesel-engine parts. The operation consists of broaching four 7-degree helical grooves across the width of the part, which is approximately 3/4 inch, and also of broaching two

half-moon surfaces through the part. The half-moon surfaces and the helical grooves are broached from a 0.945-inch hole previously machined in the bronze die-casting, the diameter across the finished half-moon surfaces being approximately 1 9/16 inches. The broach requires a stroke of 48 inches.

The short section of the broach closest to the faceplate cuts the four helical grooves as the part swivels on the ball-bearing faceplate. After the broaching of the helical grooves has been completed, a series of 90-degree V-teeth on the broach hold the work-piece stationary while the half-moon straight surfaces are broached in a definite relation to the helical grooves.

Example of Broaching on a Rotary Type of Machine.—Fig. 17 shows several sizes of shifter levers for an automobile transmission. Owing to their unusual shape, it was

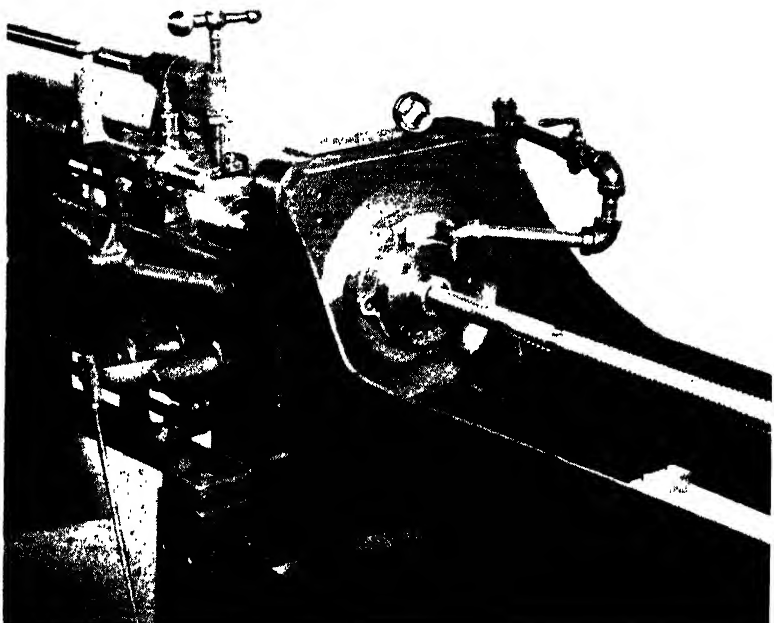

Fig. 16. Broaching Equipment Used for Broaching Helical Grooves and Straight Surfaces in the Same Operation

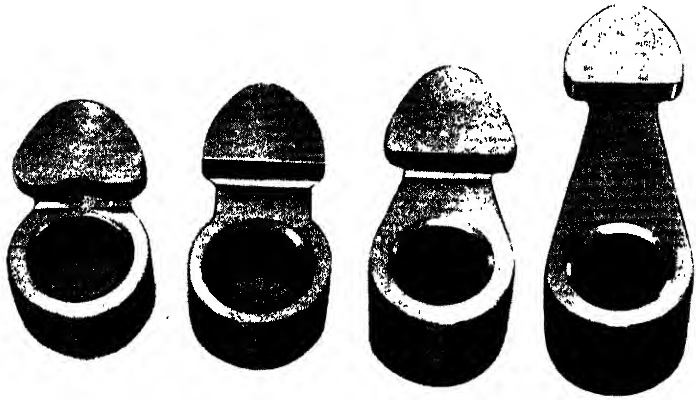

Fig. 17. Shifter Levers which are Finished by Broaching

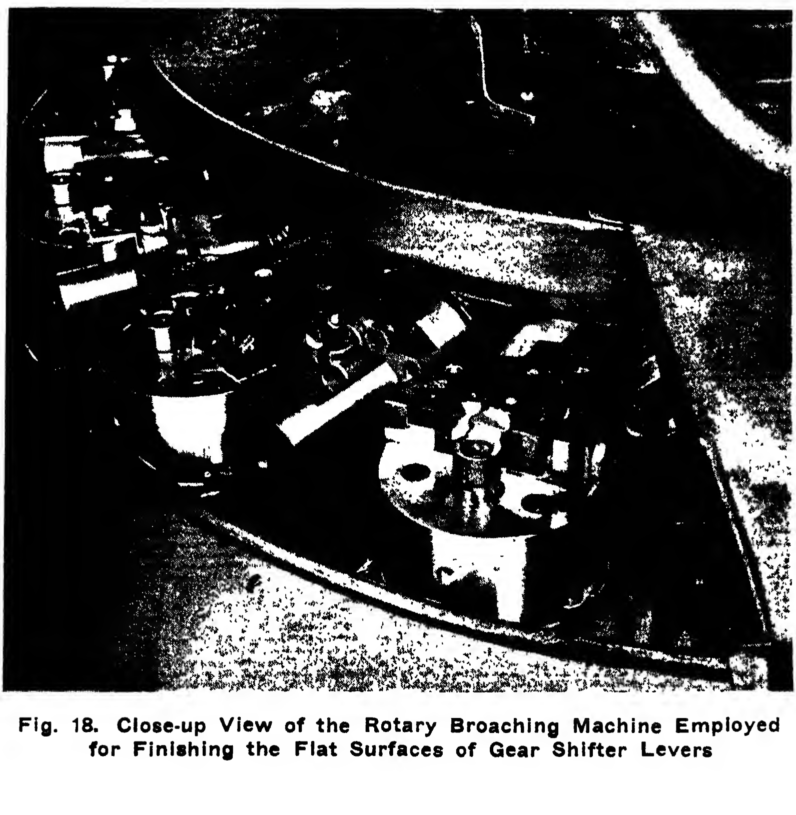

Fig. 18. Close-up View of the Rotary Broaching Machine Employed for Finishing the Flat Surfaces of Gear Shifter Levers

found necessary to use two broaching machines for these parts. The first operation is performed on a rotary type of broaching machine, a close-up view of which is shown in Fig. 18. The broaches of this machine are arranged on a head that extends around the table, except at the front, which is left open for reloading. The broaches are composed of a number of separate segments, arranged around a circular arc. Twenty-eight work pieces are accommodated at one time on the table, which is equipped with two different types of fixtures, fourteen of one kind, and fourteen of the other.

When the part is set up in fixtures of the type seen in the immediate foreground, the two large flat surfaces on the examples in Fig. 17 are broached as the parts pass around the machine, as well as the narrow step between the two larger surfaces. When the parts again reach the front of the machine, they are transferred to the second type of fixture, shown in Fig. 18, for broaching a flat spot on a lock-screw boss. This surface is broached during a second passage of the work around the broaches. In both set-ups, the part is located from the previously machined bore, thus insuring that the finished surfaces will be accurately machined in relation to each other.

The cam on the shifter pad at the top of these levers, as seen in Fig. 17, has a curve on both sides that would present a difficult machining problem if the cam were finished by means other than broaching. This shifter-pad contour is finished on a vertical duplex broaching machine, to which the parts are routed from the rotary broaching machine. The vertical machine is equipped with two fixtures, four parts being broached in one of the fixtures while the other one is being reloaded. The rather complex cam surface must be produced in two separate cuts, one side of the cam being broached with the part held in one position in the fixture, after which the part is transferred to another position in the fixture and the second side finished. Two parts are completed with each stroke of either ram.

Grinding External Surfaces of Circular Cross-Section

When cylindrical parts such as shafts, axles, pins, etc., are ground to obtain the required degree of precision or finish, or both, the complete machining operation may consist (1) of turning followed by grinding or turning and hardening followed by grinding; (2) of grinding without preliminary turning as when the amount of metal to be removed is not large enough to warrant a preliminary roughing operation. Grinding, as applied to many classes of work, is a very economical method of finishing and of obtaining accurate dimensions, even when the parts are not heat-treated. The cylindrical grinding machines used for external surfaces or shafts, etc., are also arranged in some cases for application to tapering or conical surfaces. This section shows the grinding of parts which are rotated on centers during the grinding operation. A section to follow contains examples of centerless grinding.

Grinding Anti-aircraft Gun Barrel. — The cylindrical grinding machine illustrated in Fig. 1 is grinding the long taper portion of an anti-aircraft gun barrel. For this operation, the breech end of the barrel is fitted with a solid ground plug that is supported by a center in the headstock, while the muzzle end is supported by an expanding arbor, which is held by the tailstock center. The tailstock is set over the required distance with respect to the headstock for grinding the taper. Four rests at the front of the machine prevent springing of the barrel under the grinding pressure.

A similar machine is employed for grinding the straight

cylindrical portions of the gun barrels. It is the practice to grind off stock to the extent of 0.020 inch on the diameter of all surfaces, so as to remove any concentric rings left from the turning operations and to bring the outside surface concentric with the bore. The accuracy of all remaining operations on the internal surfaces is, of course, dependent on the accuracy of the straight cylindrical external surfaces, as the barrels are located from these surfaces in subsequent operations. All external surfaces are held to within plus or minus 0.001 inch for diameter and for concentricity.

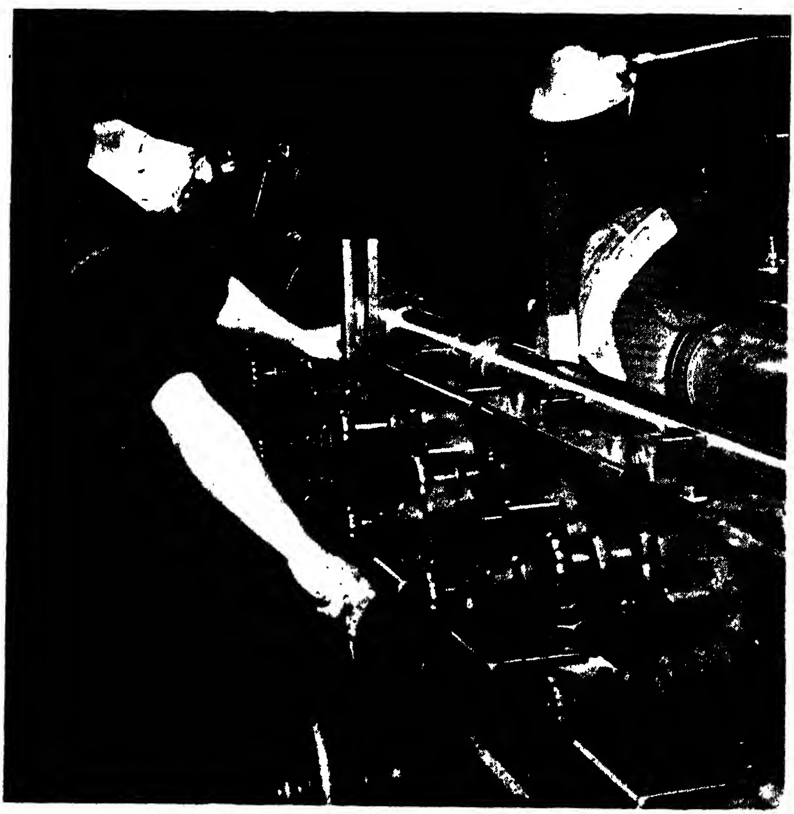

Fig. 1. Grinding the Tapered Part of an Anti-aircraft Gun Barrel on a Cylindrical Grinding Machine

An Example of Plunge-cut Grinding. — This term has been applied to grinding which is done by directly feeding into the work a wheel, the face of which is sufficiently wide to cover the entire surface being ground. In the case of parts with surfaces longer than the maximum possible wheel face, the grinding is done by in-feeding along the work at successive intervals, the face of the wheel overlapping slightly each previous cut, until the grinding of the entire length has been done, after which the work is rapidly moved past the wheel to complete it. This method is adapted to the simultaneous grinding of duplicate parts that can be

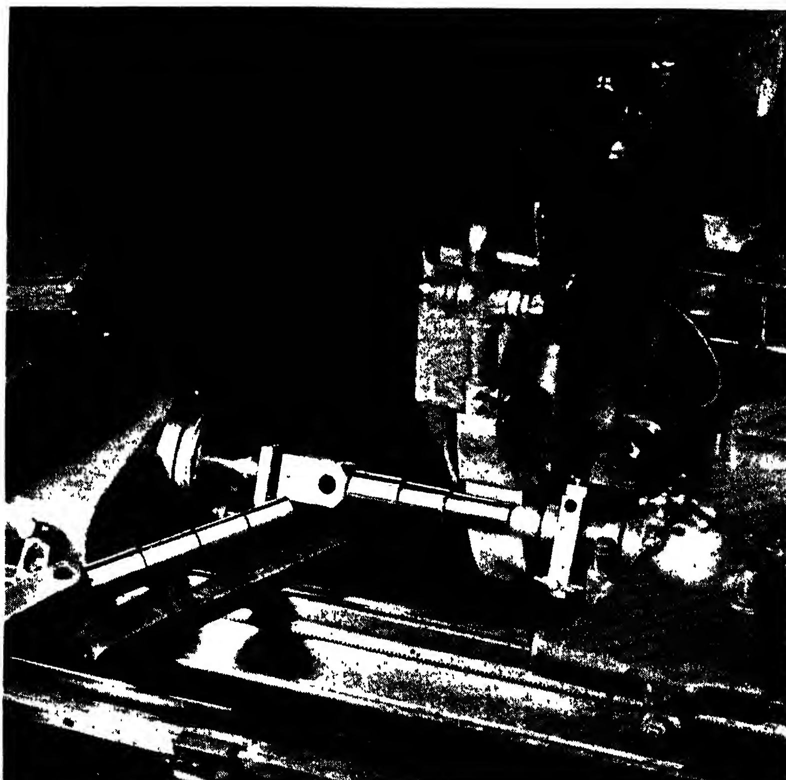

Fig. 2. Plunge-cut Grinding Three Steps on the Shanks of Airplane Wing Terminals

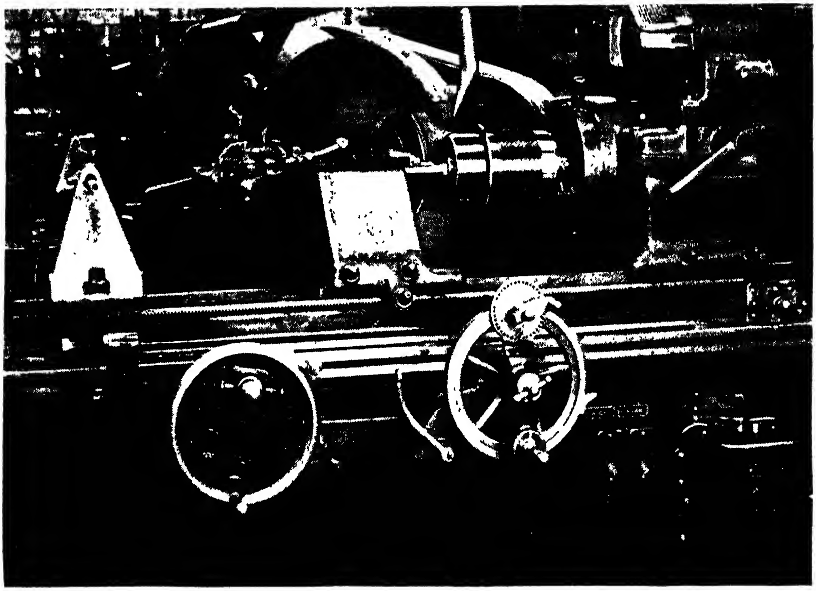

Fig. 5. Grinding with V-shaped Wheel

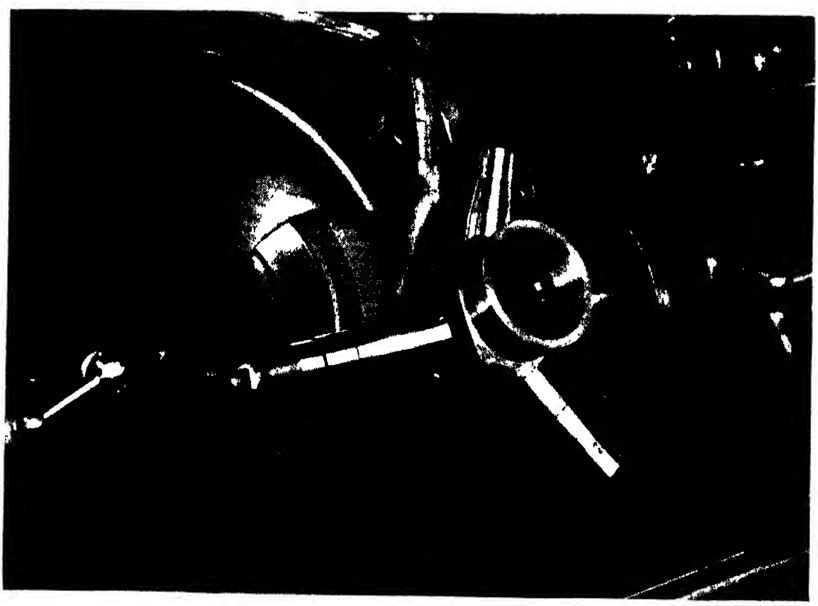

Fig. 6. Another Application of V-shaped Wheel

The grinding machine is of standard construction, except for the headstock and the provision for swinging work up to 20 inches in diameter. The wheel-base is positioned at an angle, as required for the operation. The machine was provided with an exceptionally rugged live-spindle headstock because of the size and weight of the cylinder heads, which must be carried without any outer support. The cylinder head is mounted on a hydraulically operated expanding arbor which is provided with means for locating in a lateral direction.

Grinding with Both Periphery and Side of Wheel.—Fig. 8 shows the grinding of the outside diameter and outer ends of pinion shaft bosses on the reduction-gear cage housing of an airplane engine. The outside diameter is ground with the periphery of the wheel and the boss ends with the side

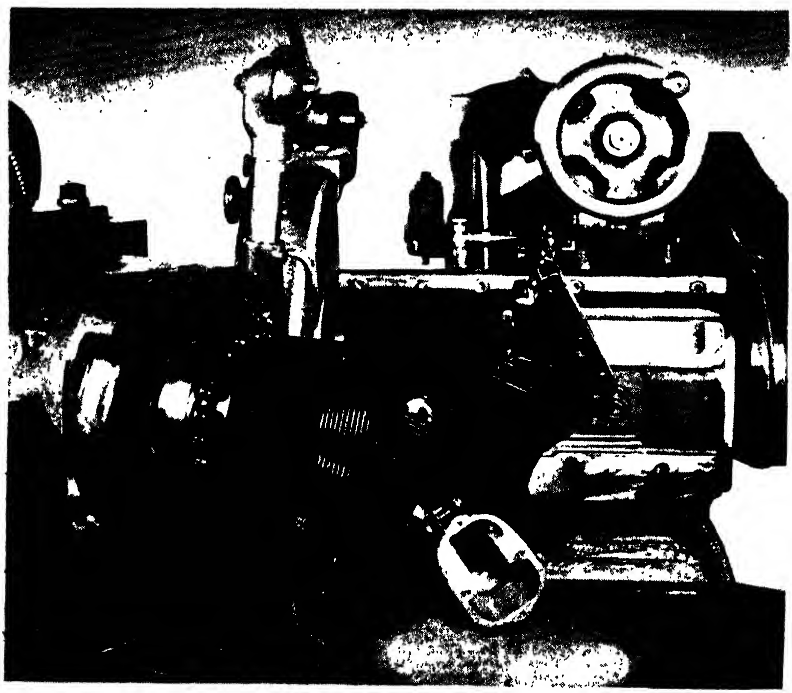

Fig. 7. Grinding Both a Flange Face and a Shoulder on Cylinder Heads by Using Wheel with a Beveled Face

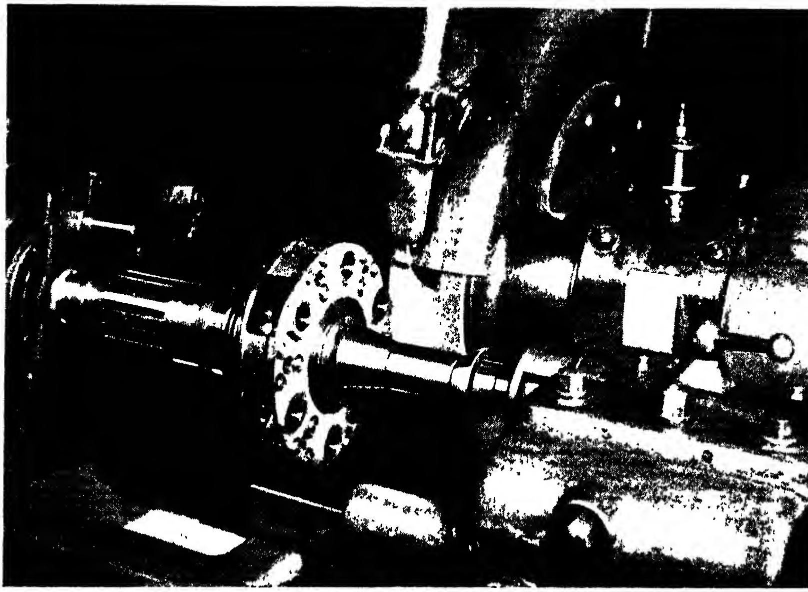

Fig. 8. Grinding with Side and Periphery of Wheel

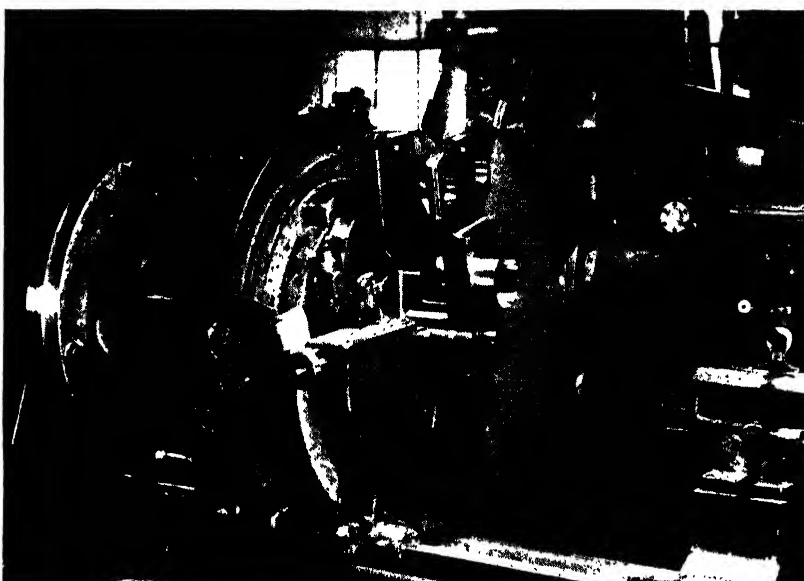

Fig. 9. Grinding Airplane Engine Crankpin

of the wheel, square within extremely close tolerances. Special centers are used for holding the work.

Grinding Airplane Engine Crankpin.— Finish-grinding the crankpin of an assembled crankshaft of an airplane engine is shown in Fig. 9. This work is done on a special machine. The crankshaft is supported by a work-holder attached to the flanged end of a heavy spindle. An outboard bearing mounted on the machine table provides additional support for the long work-holder. A clamp that closely fits the bearing adjacent to the crankshaft flange and a center point at the rear of the work-holder maintain alignment of the crankshaft. A grinding wheel 42 inches in diameter is necessary for this job because of the projecting flanges of the crankshaft. The diameter of the crankpin is held within a total tolerance of 0.0002 inch.

External Grinding with Small Wheel in Restricted Space. —Many grinding operations in airplane engine plants are similar to the practice followed in other metal-working shops. There are, however, some parts peculiar to radial aircraft engines which require special machines or fixtures, or unusual adaptations of standard equipment. In the operation illustrated in Fig. 10 a wheel of unusually small diameter is necessary for the cylindrical grinding of a reduction-gear spider hub, because of the small space between the pinion bearing bosses and the hub.

Grinding Propeller Shaft Trunnions. — An interesting grinding operation is shown in Fig. 11. This consists of finishing the three trunnions on a propeller shaft by the application of a universal grinding machine, built for handling work up to 38 inches swing. Grinding is accomplished by applying the side of a dish-shaped wheel to the revolving trunnions. The propeller shaft is held in a fixture attached to the nose of the live work-spindle. During grinding, the propeller shaft is clamped rigidly at two points. Full provision is made for locating and indexing.

The procedure is to grind one trunnion, unclamp the propeller shaft, index it through 120 degrees, reclamp it, and grind the second trunnion. At the end of this step, the

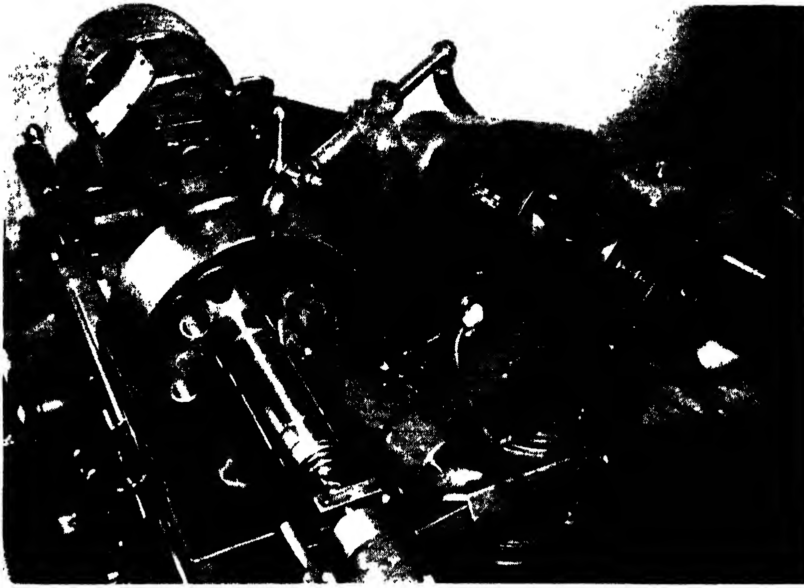

Fig. 10. Operation Requiring a Small Wheel

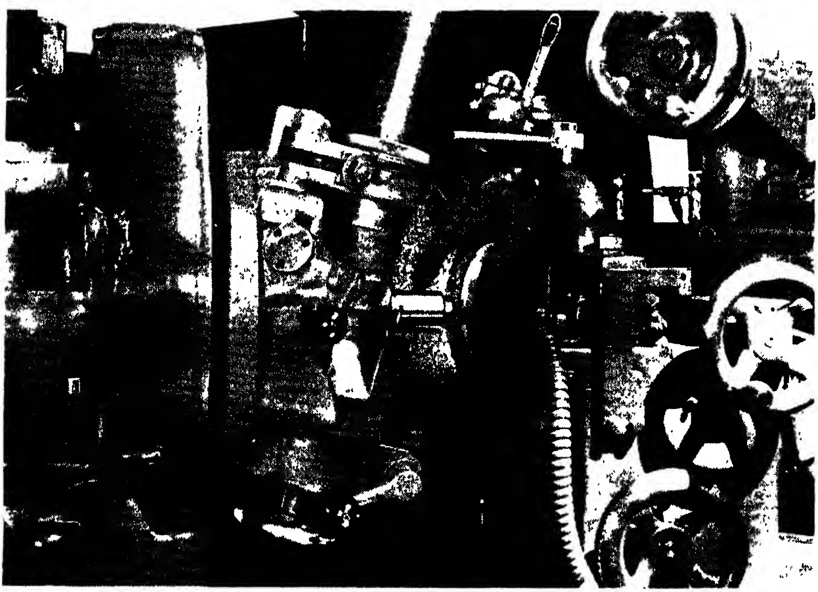

Fig. 11. Grinding All Three Trunnions of Propeller Shaft by Employing Indexing Fixture

propeller shaft is indexed through another 120 degrees for grinding the third trunnion.

A unique wheel-truing device, in the form of a compound slide, is used, so that the diamond can be both advanced toward the wheel and fed across the wheel face. As the accuracy of the fillet where each trunnion joins the main body of the propeller shaft is important, a means for radial truing of the grinding wheel is also supplied.

Grinding Holes or Internal Surfaces

The finishing of holes by grinding is applied extensively in the manufacture of parts requiring accurate dimensions. The part to be ground usually is held by a chuck or work-holding fixture, and grinding is done by rapidly revolving a wheel that is somewhat smaller than the hole and is traversed through it. Gaging equipment for determining readily when the hole has been ground to the size required is one of the important developments in internal grinding practice, especially in the production of duplicate interchangeable parts. The centerless grinding principle has also been utilized in connection with internal work as explained in the following section.

Internal- and Face-grinding Aircraft Parts.—Eighteen different aircraft parts are finished by the internal grinder shown in Fig. 1, which was installed in a plant for handling a diversified range of work. Since most of the work-pieces involve face-grinding, as well as internal grinding, the machine is equipped to handle both operations, there being a cross-slide under the work-head which enables quick indexing for grinding either a hole or a face. The handwheel table feed provides for plunge-cut grinding of faces, and there is a positive table stop for controlling the depth of such cuts. The part seen in the chuck and on the machine table is a gun bracket. The operation consists of finish-grinding a 2.750-inch diameter bore and a shoulder at one end of the bore. Other typical parts ground in this machine include a distributor drive gear, magneto pinion, magneto ball-bearing housing, and generator drive gear.

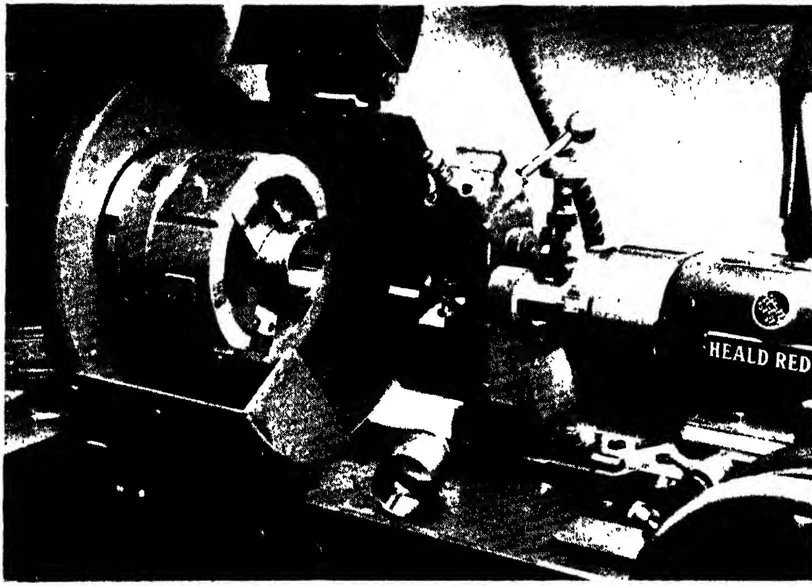

Fig. 1. Internal- and Face-Grinding Operations

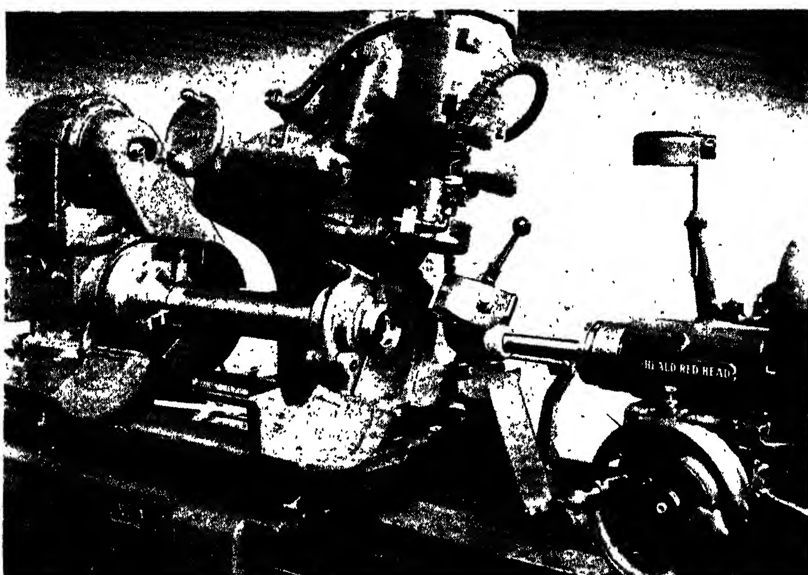

Fig. 2. Grinding Long Spindle

Grinding Long Spindles Internally.—Long spindles for lathes and milling machines are ground with the internal grinder shown in Fig. 2. This machine is provided with an extended bridge for the accommodation of long work. Spindles up to 31 1/2 inches long by 4 inches outside diameter can be ground, not only in the internal bores but also on tapered shoulders and on an external face. These grinding cuts can all be taken at the same set-up of the work.

The spindle being ground is supported at one end by a three-jaw chuck attached to the work-head, and at the other end by a pillow block. Both the work-head and pillow block are mounted on the swivel-plate of the extended bridge.

The external face on the end of the spindles is ground by means of a face-grinding attachment, mounted on the rear of the swivel-plate, which is fed vertically for the oper-

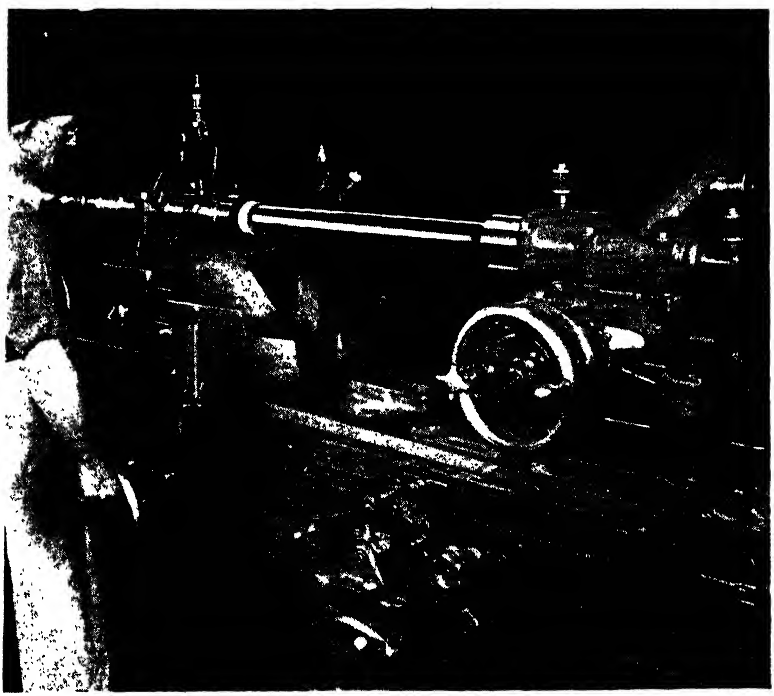

Fig. 3. Grinding the Bore of a Cylinder for Aircraft Landing Gears

ation. Tapered shoulders are ground by the plunge-cut method, a formed wheel being used which is mounted on the horizontal spindle seen at the right. This wheel is fed to the work by means of the table feed. The same wheel is used for grinding straight bores.

Grinding Aircraft Landing Gear Cylinders.—After a straddle-milling operation on the cylinder lugs, the cylinders are ground internally in the machine shown in Fig. 3. In the operation illustrated a cylinder is being ground to a diameter of 3.062 inches within plus 0.002 inch, minus nothing, stock to a depth of 0.003 inch being left all around the internal surface for removal by honing. Landing gear pistons are ground on this machine to three different diameters within limits as close as plus 0.001 inch, minus nothing.

Grinding Bores of Radial Engines for Tanks.—The internal grinding operation shown in Fig. 4 is for finishing the bore of a cylinder on an Army tank. After the cylinder head and barrel has been assembled, a chucking grinder is used for grinding the bore of the cylinder barrel. In order to insure accurate positioning of the work in the machine, a large circular adapter with a ground ring is slipped over the ground external surface or skirt at the front end of the cylinder barrel and clamped to the barrel flange. This ground adapter ring fits the hollow machine spindle closely. Likewise, an aluminum casting with four arms that extend radially from the center is clamped to a finished pad on the cylinder head. Each arm has a hardened steel insert ground to a radius corresponding with that of the hollow machine spindle, and this insures that the head end of the cylinder assembly will be held accurately in line with the barrel end during grinding.

Approximately 0.025 inch of stock on the diameter is ground from the cylinder barrel bore in this operation, the tolerance on the diameter being 0.001 inch. At the outer end, the cylinder barrel is ground to a taper of 0.0005 inch within this tolerance. Close control of the operation is afforded by an indicator on the front of the machine, which

is graduated to 0.0001 inch. The cylinder barrel has a nominal diameter of 5.125 inches and is 8 1/2 inches long.

When the machine has been loaded, an air chuck at the left-hand end of the headstock brings a plunger against an opening in the aluminum locating casting attached to the cylinder head, so as to deliver coolant to the inside of the work for the grinding operation.

Internal Grinding Operation Illustrating Application of Sizing Device.—Hardened-steel rocker arms, of the construction seen in the chuck of the machine shown in Fig. 5, are ground in the bore at the rate of twenty-five pieces per hour. This operation is performed by an internal chucking grinder equipped with a sizing device, which shows the progress of the grinding wheel in removing stock and indicates when the operation is completed. Approximately

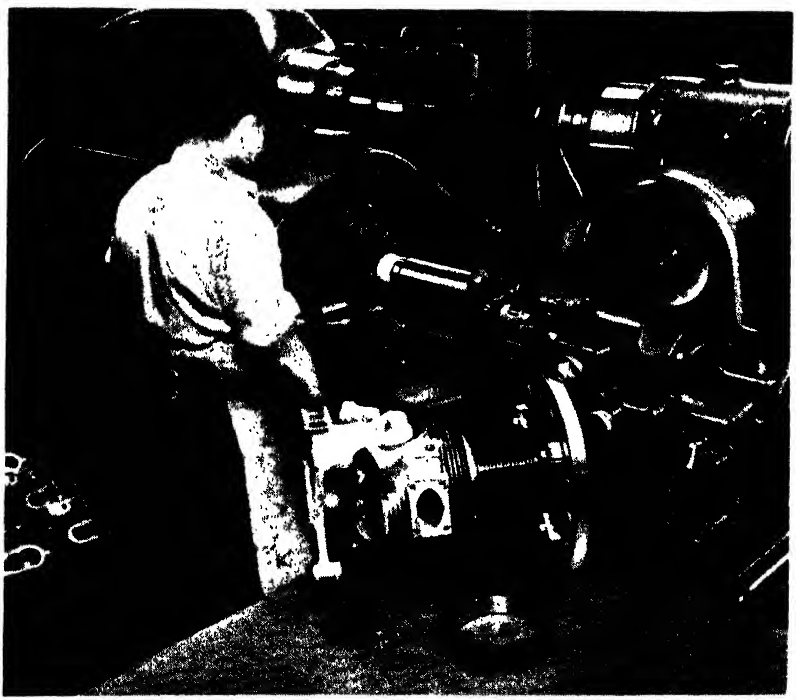

Fig. 4. Chucking Grinder Employed for Rough- and Finish-grinding the Bore of Cylinder Barrels

Fig. 5. Grinding Rocker Arm Bores

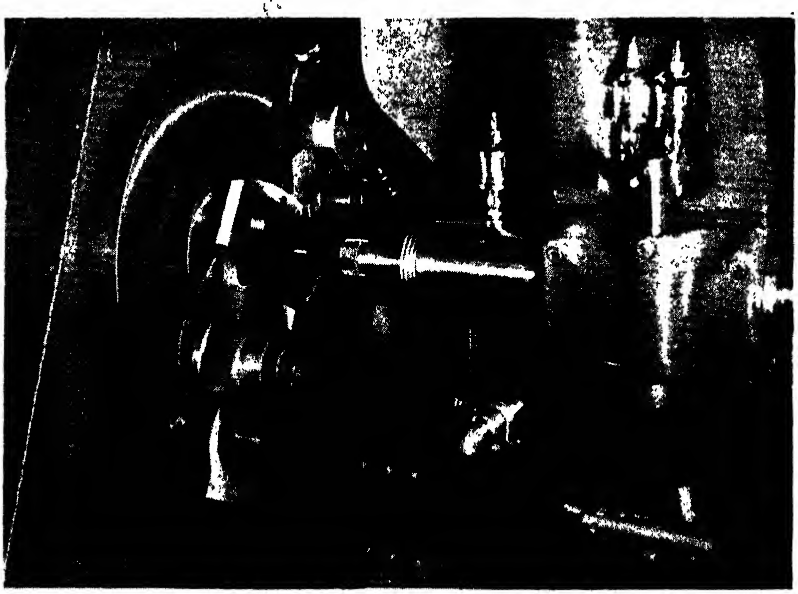

Fig. 6. Grinding Two Holes in Crank-arms

0.015 inch of stock on the diameter is ground from the bore, the required size being attained within limits of plus or minus 0.0005 inch.

Grinder Equipped with Indexing Fixture for Grinding Two Holes.—One of the crank-arms for a built-up crankshaft used in airplane engines is shown in Fig. 6 in a machine employed for grinding two holes. The machine is an internal chucking grinder. It finishes the holes to size within plus or minus 0.0005 inch while removing from 0.015 to 0.020 inch of stock on the diameter. The fixture enables the crank-arm to be indexed for grinding the two holes in one chucking. Fifteen holes can be ground per hour, on the average. The same machine equipped with a different fixture is employed for grinding the larger hole at the opposite end of the crank-arm.

Grinding Nitrided Cylinder Barrels.—Nitrided cylinder barrels for liquid-cooled engines are ground internally at the rate of three barrels per hour by employing the internal chucking grinder shown in Fig. 7. These barrels are finished to the desired diameter, and straight within 0.0002 inch, from 0.005 to 0.010 inch of stock on the diameter being removed by the grinding wheel. A sizing device, equipped with a finger that rests on the surface being ground, indicates when the bore has reached the specified size.

Grinding Airplane Propeller Hubs.—Each of the three bores in the airplane propeller hub barrel seen in the machine in Fig. 8, is ground in the bore, on the internal face, and along a fillet on an internal chucking grinder. This illustration is from a prominent airplane plant in England. The work is completed at the rate of one part per hour. The propeller hub barrel is of heat-treated steel, and the dimensions of the surfaces ground must be held within a tolerance of plus or minus 0.001 inch. Approximately 0.025 inch of stock is removed from the various surfaces. The fixture is of an indexing design which enables each bore to be presented to the grinding spindle with one set-up of the work in the fixture.

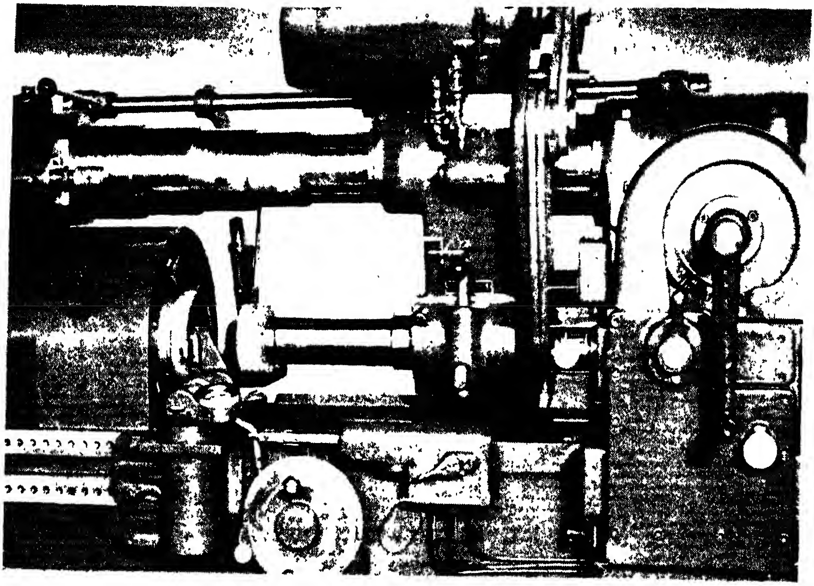

Fig. 7. Grinding Nitrided Cylinder Barrels

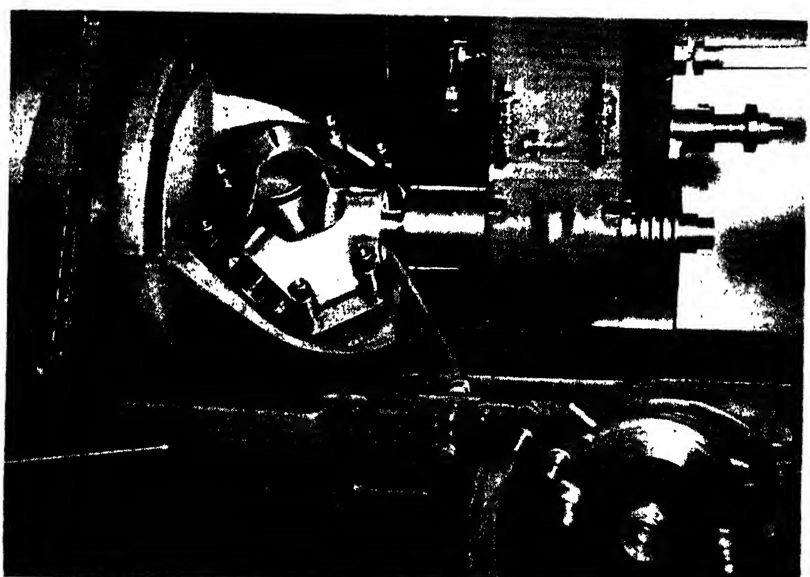

Fig. 8. Grinding Airplane Propeller Hubs

Grinding Opposite Ends of Bore in Countershaft Gear.—Tooling designed to insure the required accuracy in grinding opposite ends of the bore in a countershaft gear is shown in Figs. 9 and 10. The bores ground in this operation are about 1 1 8 inches in diameter and 1 1/4 inches long. Although the distance across the two surfaces is approximately 7 inches, the bores must be straight within 0.0005 inch and in true alignment within 0.001 inch. The diameter tolerance is also 0.001 inch. Previously, the two bored surfaces were ground with the part located from the teeth of the two gear sections at the ends of the part, and grinding wheels were applied from each end, but it was decided that the operation would be facilitated if the work could be located from centers.

A pot chuck with a hollow center at the right-hand end was designed for this purpose, as seen in Fig. 10. The hole through this center is large enough for the grinding wheel to pass through. At the left-hand end of the chuck is a solid center, which is advanced to or withdrawn from the work through the operation of a lever. The use of centers in the extreme ends of the work, which are larger in diameter than the surfaces to be ground, insures accurate location of the part.

Both holes are ground in one set-up by a single wheel. Another advantage is that the use of a single wheel enables the operator to "spark out" the bores in finishing them to size, and the wheel can be withdrawn without any contact against the finished surfaces, if desired. The headstock spindle can be run at various speeds. Another feature is a cam that enables the pot chuck to be rotated freely by hand into the loading position. By the use of this equipment, one man can grind seventy-five gears an hour, operating two machines.

Grinding Conical Surfaces.—In machining the hub forgings for airplane propellers, a series of grinding operations is performed on the cross and barrel bores by chucking grinders. In Fig. 11 is shown a machine employed for grinding two conical seats at opposite ends of the cross-bore in line and concentric within 0.002 inch. The conical

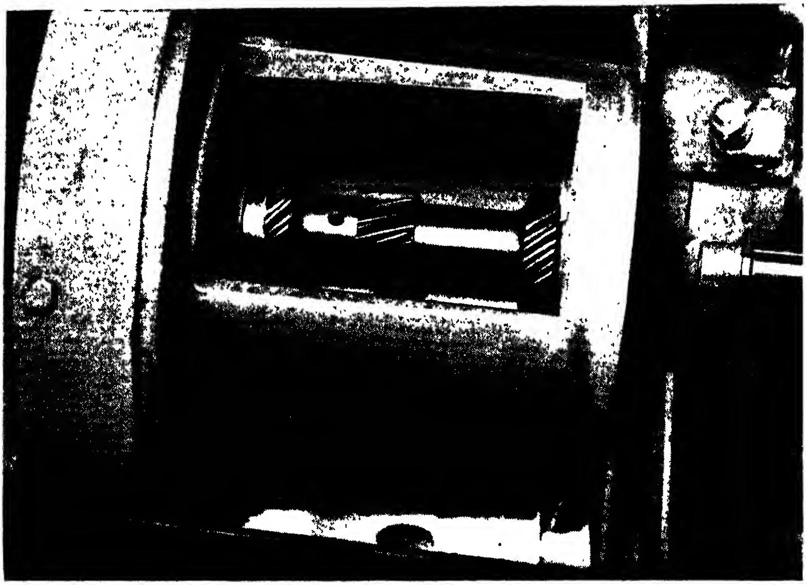

Fig. 9. Grinding Bores of Countershaft Clutch Gears

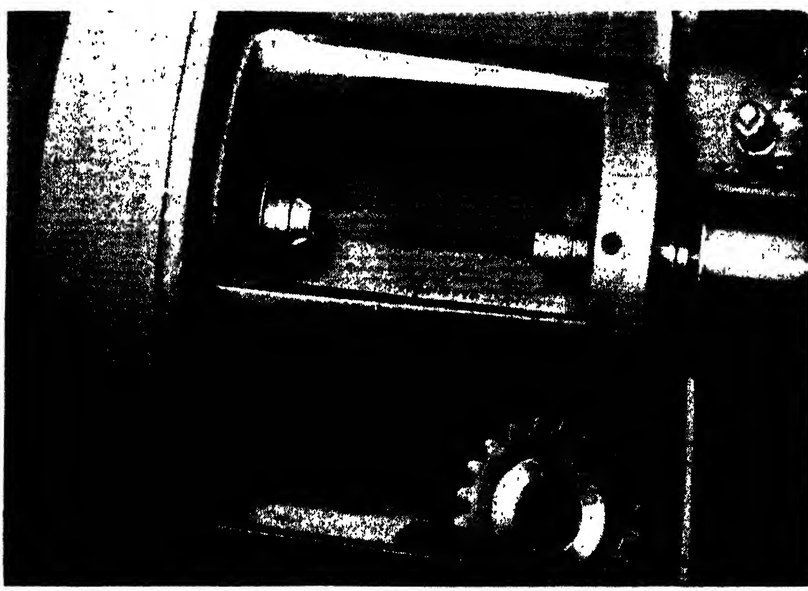

Fig. 10. Pot Chuck in Fig. 9 Shown Unloaded

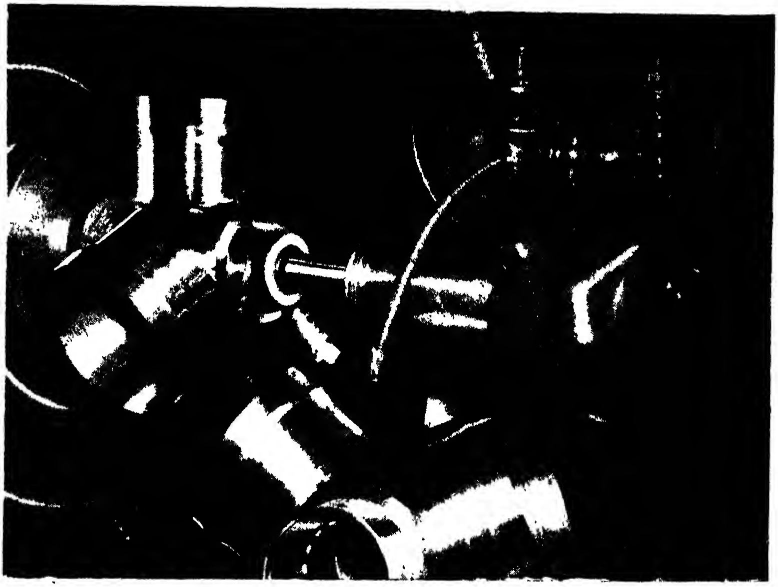

Fig. 11. Grinding a Conical Seat

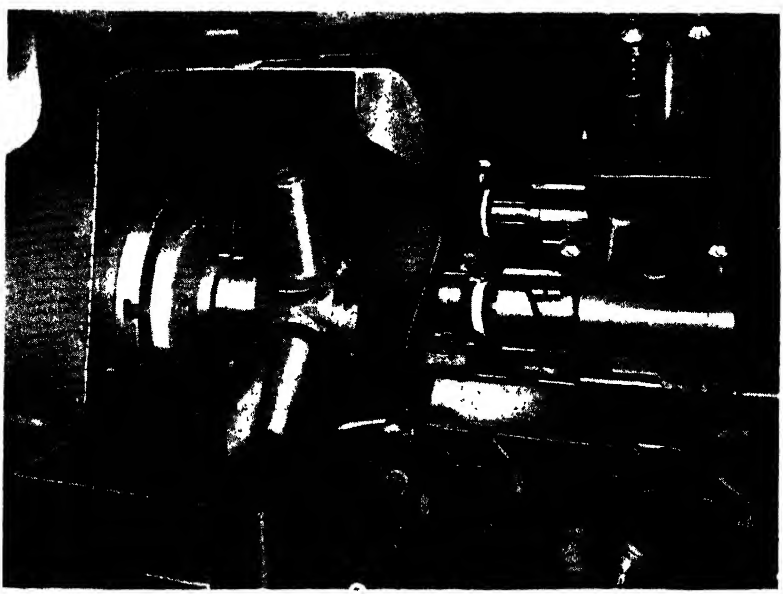

Fig. 12. Grinder with Two Wheel-spindles

seat in one end is ground to an angle of 15 degrees, while the seat in the opposite end is finished to an angle of 30 degrees. One seat is ground in a lot of propeller hubs, and then the set-up is changed for grinding the other conical seat in the same lot.

Fig. 12 shows a chucking grinder used for grinding a 15-degree seat in one end of the main bore of spiders, and a 30-degree seat in the opposite end. Both of these operations are performed in one machine by the use of two separate grinding spindles and by turning the work end for end on the arbor.

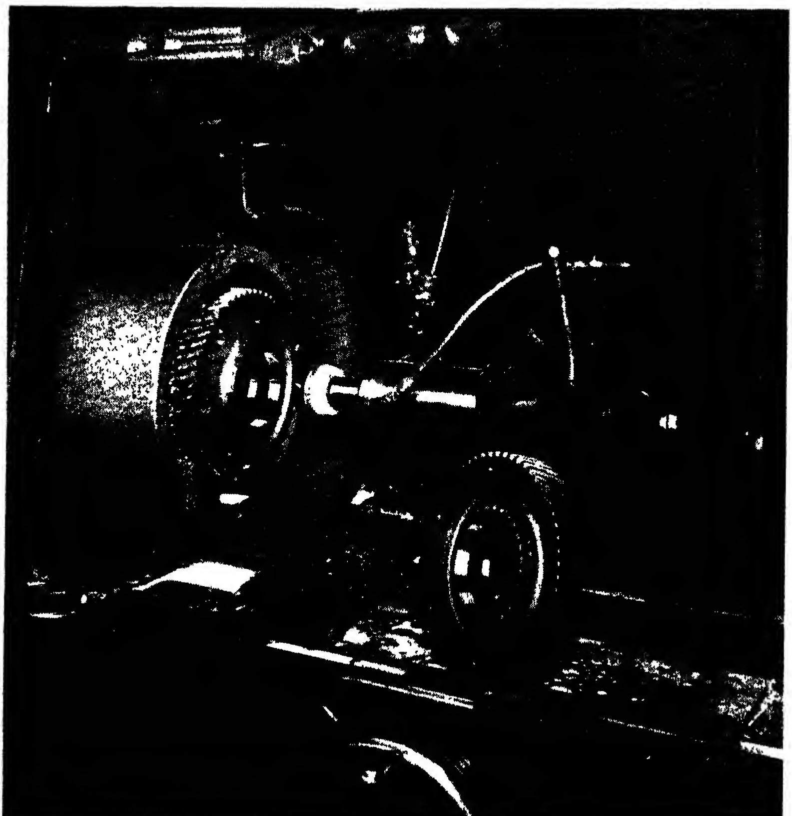

Fig. 13. Machine Arranged for Grinding Beveled Surfaces which Incline in Opposite Directions

Grinding Beveled Surfaces which Incline in Opposite Directions.—In Fig. 13 is shown a chucking grinder set up for grinding bevel surfaces at both ends of the bore in a helical synchronizing gear. The tapers are held within an accuracy of plus 0.0007 inch, minus nothing. Use is made of a grinding wheel trued to a double bevel. When the grinding wheel has been fed into the work until the first half is in line with the front tapered surface of the gear bore, the grinding spindle is rocked sidewise to permit a traverse cut on the gear surface. When the grinding of this surface has been completed, the wheel spindle is rocked back into line with the center of the gear, and is then advanced into the work to bring the second bevel of the grinding wheel into line with the bevel surface on the rear side of the gear. The grinding spindle is then rocked toward this bevel surface for a traverse grind, after which the spindle is returned to the center of the gear and the grinding wheel withdrawn. The rocking movements of the arm which carries the grinding spindle are effected by a cam at the back of the grinding machine. The cylindrical surface in the center of the gear is approximately 4 1/2 inches in diameter.

Centerless Grinding Operations

The centerless grinding method is very rapid as well as accurate, and it is possible to finish quite a large variety of work by this method. The part to be ground, instead of rotating upon centers at each end, is rotated and traversed between a high-speed grinding wheel and a low-speed regulating wheel, while supported by a suitable guide or work rest. When the centerless method is applied to straight cylindrical parts, the work simply passes between the grinding and regulating wheels, and the latter imparts to it uniform rotation and an axial feeding movement. Duplicate parts follow in quick succession so that the grinding operation on a single piece often requires a few seconds only. Several passes may be required, depending upon the accuracy of the unground part and the amount of stock to be removed.

The *through-feed method* just described cannot be employed when there are shoulders or enlarged sections. Parts with a shoulder may be ground by the *in-feed method*, in which case the length of the ground surface is limited by the wheel width. For tapering work, the end-feed method is employed. The tapering part is fed in mechanically or manually to a fixed end-stop, and either the grinding or regulating wheels, or both, are formed to the required taper. The centerless principle has also been applied to internal work as shown by examples to follow.

The grinding of relatively small parts may be done automatically by equipping the machine with a magazine, gravity chute, or hopper feed, provided the shape of the part will permit using these feeding mechanisms. Rates of production vary widely according to the character of

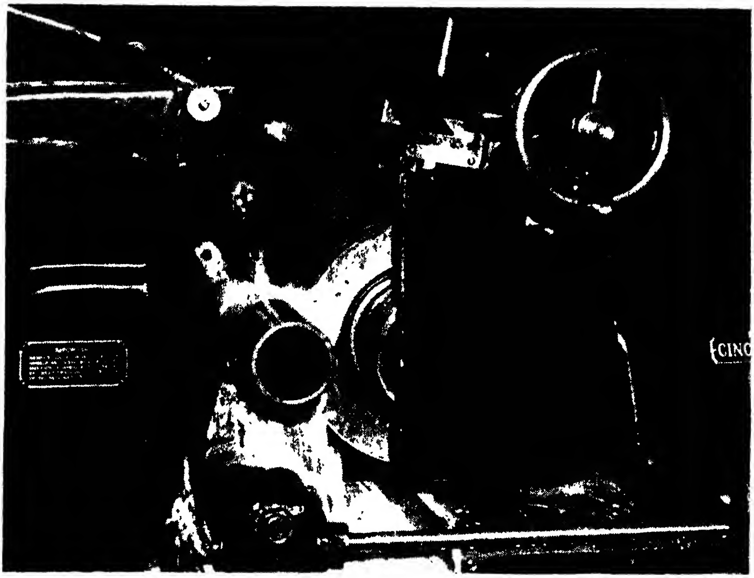

Fig. 1. Centerless Grinding Tubular Shafts

Fig. 2. Example of Taper Grinding on Centerless Machine

the work, the material, the accuracy and finish required, and other factors. For example, production often varies from two or three hundred up to several thousand pieces per hour. As a general rule, parts ground by the through-feed method require two passes and from 0.010 to 0.015 inch of stock is removed; however, when an extra-fine finish and extreme accuracy are essential, as for piston-pins, etc., the number of passes is increased. Most work is ground either by the through-feed or in-feed methods. The rate of production with the through-feed method depends chiefly upon the amount of stock to be removed, whereas, with the in-feed method, the production rate is limited to a considerable extent by the time required for loading and unloading.

Finishing Tubes by Centerless Grinding.— In Fig. 1 is shown a centerless grinding machine finishing the outer surface of a chromium-molybdenum tube. These tubes are used in conjunction with the beaching gear for flying boats. The tubes are 3 1/2 inches outside diameter by 18 inches long. They must be of the required diameter, round, and straight within close limits. The same machine is used in this shop for grinding a large variety of other work, including bronze bushings 3 1/2 inches outside diameter by 3 inches long, and parts of smaller diameter.

Grinding Taper Rollers.—Taper rollers are ground on the tapered surface by the centerless grinding machine shown in Fig. 2. This machine is equipped with a special loading device that feeds each roller between the grinding and feeding wheels to a positive stop. The work is then ejected automatically. Rollers from 1 1/8 to 2 15/16 inches diameter at the large end are ground to an angle of 14 1/2 degrees. Diameter and length dimensions must be maintained within plus or minus 0.0001 inch.

Grinding Chromium-plated Tubes. — The centerless grinder shown in Fig. 3 is finishing airplane landing-gear fulcrum tubes to a diameter of from 1.9960 to 1.9965 inches. The tubes are 10 inches long. This operation is performed after the tubes have been heat-treated and chromium-plated to a thickness of from 0.002 to 0.003 inch. The tubes

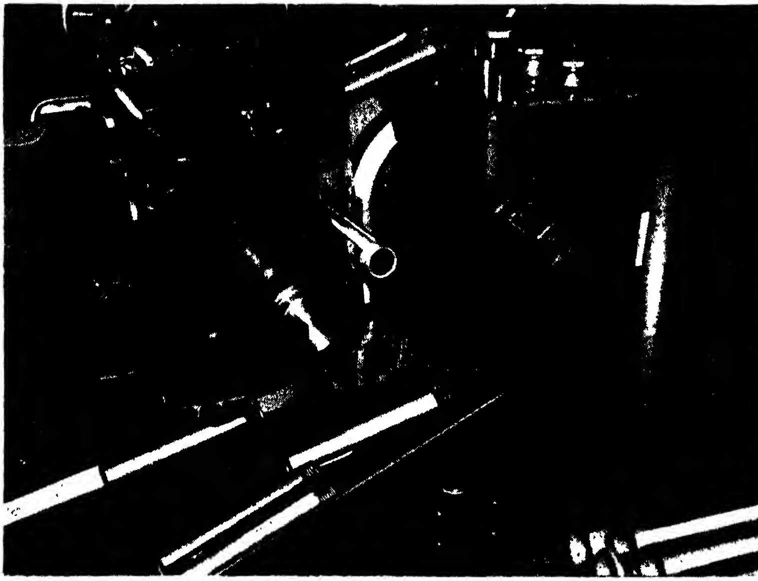

Fig. 3. Finishing Landing-gear Fulcrum Tubes

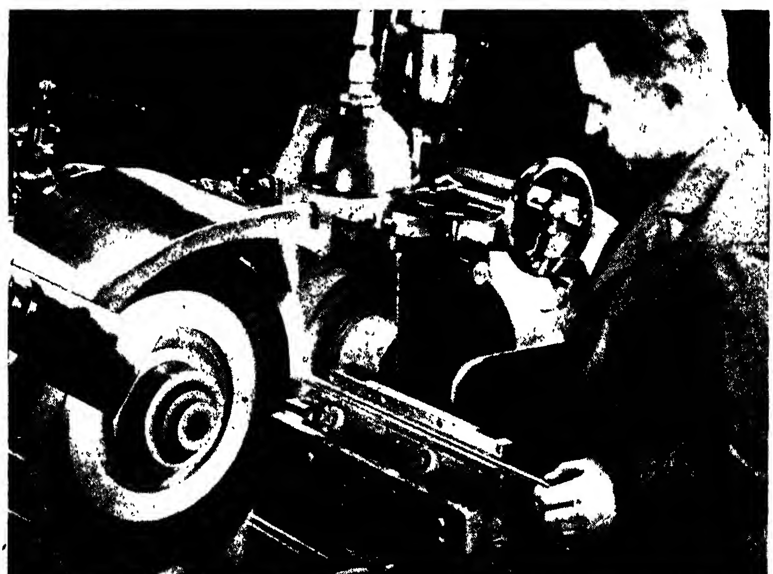

Fig. 4. Grinding Shafts by Centerless Method

are also ground in this machine immediately after the heat-treatment and before they are plated. The threads seen on the parts are ground after chromium-plating.

Grinding 22-Inch Shafts.— Fig. 4 illustrates the centerless grinding of camshaft rocker lever shafts. These shafts are 22 inches long, are ground to a diameter of 0.4995 to 0.5000 inch for their entire length with one pass between the wheels of the centerless grinder.

Grinding Universal-Joint Pins.—Universal-joint pins are ground to size within 0.0006 inch, and round and straight within 0.0001 inch, in the centerless grinding machine illustrated in Fig. 5. Two operations are performed, about 0.012 inch of stock being removed in roughing and 0.003

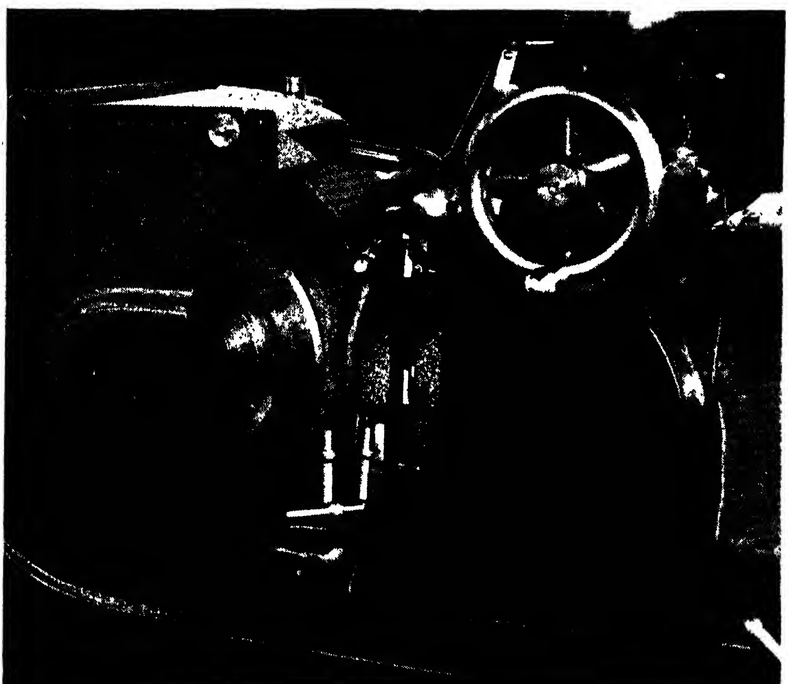

Fig. 5. Grinding Cylindrical Surfaces on Universal-joint Pins with a Centerless Grinding Machine

inch in finishing. The average production is fifty pieces an hour. The machine is equipped with a special in-feed work-rest and a hinged loading mechanism.

The work-piece is laid in a support cradle attached to a hinged member, the handle of which is seen projecting toward the front of the machine. This handle is shown in the loading position, where it is normally held by a spring. The lever has a large arc movement to permit the pins to be lowered to the work-rest without interference from the grinding and regulating wheels. The unground ball section of the pins enters a clearance space between the wheels and the work-rest blade.

The loading lever is held down by the operator during the grinding action, so that the work is free to ride on the work-rest blade. At the end of the grinding operation, the lever returns to the position shown, so that the operator can conveniently remove the ground piece and replace it with an unground pin.

Example of Internal Centerless Grinding.—Internal Grinding machines based upon the centerless principle utilize the outside diameter of the work as a guide for grinding the bore which is concentric with the outer surface. In addition to straight and tapered bores, interrupted and "blind" holes can be ground by the centerless method. When two or more grinding operations must be performed on the same part, such as roughing and finishing, the work can be rechucked in the same location as often as required.

Cylinder sleeves and liners from 4 to 8 inches outside diameter and up to 16 inches long are ground on the internal centerless grinding machine shown in Fig. 6. This view of the machine was taken with the camera directed toward the loading end, the grinding wheel being on the far side of the work. The cylinder sleeves are both located and driven from the periphery by means of a regulating or drive roll, a pressure roll, and a support roll. The grinding wheel is passed back and forth through the revolving work to grind it to the desired diameter. A close concentricity between the bore and the outside diameter is maintained. Sleeves of thin wall section can be ground accurately, and

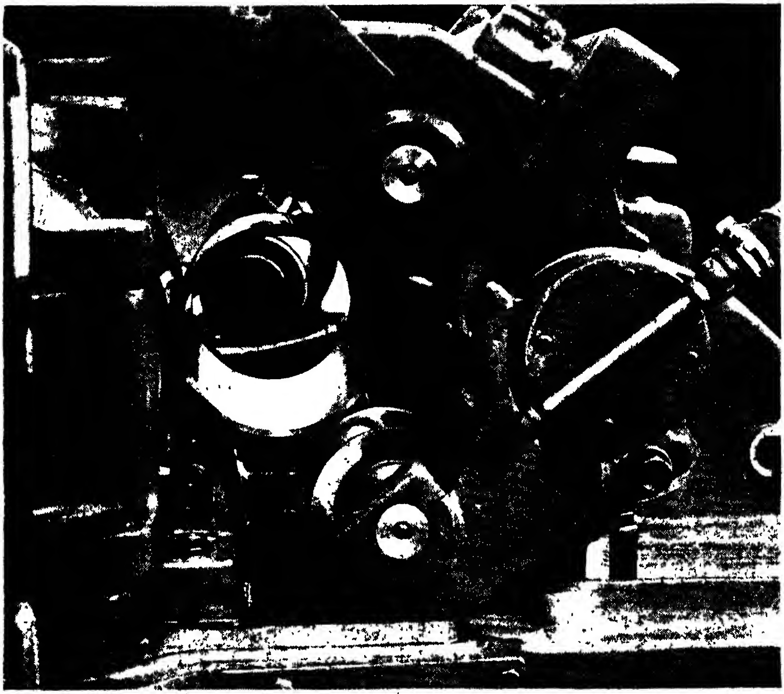

Fig. 6. Cylinder Sleeves for an Airplane Engine are Ground Internally in this Centerless Type of Machine

work can be rechucked without destroying the axial relation between the bore and the periphery.

The machine embodies a wheel-head construction by means of which an unusually fine finish can be produced. This consists of a wheel-head mounted at an angle on the cross-slide. The construction also enables the use of a much smaller grinding wheel than would be necessary with a conventional design.

Grinding Airplane Engine Cylinder Bores by Centerless Method.—The operation of finish-grinding the bore of complete airplane engine cylinder assemblies just prior to the final honing operation is performed on the internal centerless grinder shown in Fig. 7. For loading, the section of the runway that acts as a bridge between the machine proper and the centering device seen at the left-hand side

is raised on hinges, and the cylinder assembly is then inserted in an aluminum drum equipped with hardened and ground steel rims. A hydraulic mechanism next swings the fixture vertically through 90 degrees and raises it to the level of the runway along which it is rolled to the centering device. Then two pairs of hardened rollers, actuated by a separate electric motor, raise the fixture from the rails and cause it to rotate slowly for inspecting by means of an indicator with a long extension arm. This device, which is visible at the left-hand side of the illustration, is slid into the barrel to check it for concentricity, which must be held to within 0.001 inch. The power used to revolve the work

Fig. 7. Finish-grinding Cylinder Bores on an Internal Centerless Grinder Equipped with Ingenious Loading and Inspecting Mechanisms

in this preliminary inspection is then shut off, and the part is lowered to the rails to remain there until the part in process is completed.

When that part has been ground, the front of the machine is opened, and the fixture holding the part is rolled out on the bridge, which then swings down to carry the finished part to the unloading position. At the same time, the bridge gap is closed by means of the hinged rails, so that the new part can roll across the bridge and into the machine, where it is engaged by the set of driving rollers. The front of the machine is now closed, and grinding begins, the size of the hole being constantly checked by a dial indicator attached to the machine and connected to an arm equipped with a diamond point. As the bore approaches the final size, it is checked with a special gage between each few passes of the grinding wheel.

Grinding Flat or Plane Surfaces

A great many machine parts have plane bearing or other surfaces which must be accurate as to form and dimensions, and different types of machines have been developed for grinding them. Some of these machines have wheels of the straight or disk type and work-holding tables which operate with a reciprocating motion. Other surface grinders have wheels of the cylinder type, and the work-table rotates to bring the work surface, or surfaces, under the edge of the wheel. Typical examples of surface grinding on both types of machines are presented in this section.

Grinding Surfaces of Breech-blocks.— Breech-blocks for 3-inch anti-aircraft guns are surface ground on all four sides by the hydraulically operated surface grinder shown in Fig. 1. As many as thirty of these blocks, which measure 11 1/2 by 6 by 5 1/2 inches, can be loaded at one time on the two magnetic chucks which are each 5 feet long by 20 inches wide. A tolerance of 0.002 or 0.003 inch is allowed on the breech-blocks as they leave this machine, but they are actually ground to size much closer than that. These blocks are hammered steel forgings.

Grinding Connecting-rod Bolt Lugs.— Fig. 2 illustrates the grinding of bolt lugs on three connecting-rods. These connecting-rods are mounted on their joint faces on a fixture attached to the surface grinder. Quick-acting clamps grip each rod on two sides.

Grinding Both Vee and Flat Ways of Lathe Bed.—Both vee and flat ways of small lathe beds are ground simultaneously by the use of a hydraulic surface grinding machine

Fig. 1. Surface Grinding a Number of Breech-blocks

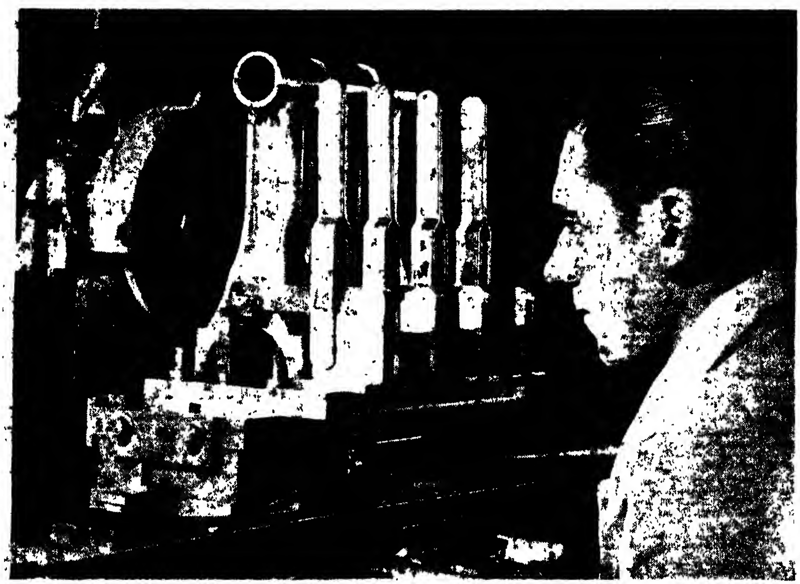

Fig 2. Grinding Connecting-rod Bolt Lugs

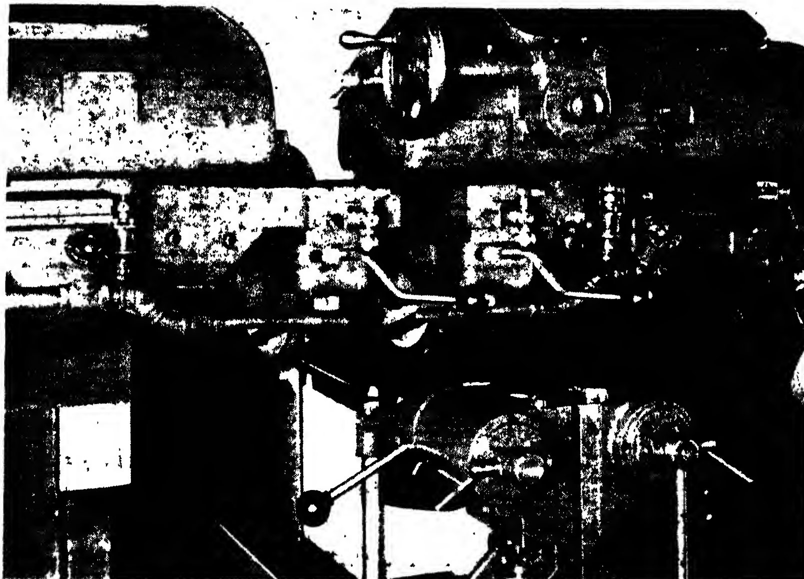

Fig. 3. Grinding Vee and Flat Lathe Bed Ways Simultaneously

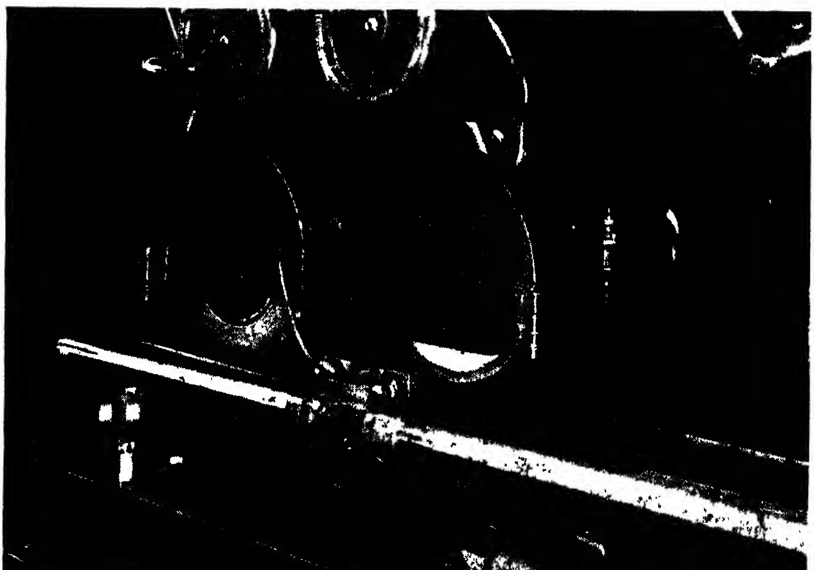

Fig. 4. Straddle-Grinding Surfaces on Landing Gear Parts

equipped with two grinding heads, as illustrated in Fig. 3. Both grinding wheels are form-dressed by means of truing devices mounted on the machine table. Lathe beds are ground to a high degree of accuracy by this method, and in approximately one-third of the time required for hand-scraping. In addition, interchangeability of beds is attained.

Grinding Parts of Airplane Landing Gear.—The lugs or ears at one end of the cylinders and pistons are straddle-ground in the hydraulically operated surface grinder shown in Fig. 4, which is equipped with two grinding heads. Here two pistons are seen mounted end for end on the machine table, the lugs being located radially by keys on a fixture which are inserted between the previously milled inner surfaces of the lugs. This set-up is of the utmost importance, because the outer faces of the lugs after the grinding operation must be the required distance from the center line of the piston within 0.002 inch. The ground width across the lugs must be 2.249 inches within plus 0.001 inch, minus nothing. Obviously, the milling operation on the inside of the lugs must also be performed with extreme accuracy.

In front of the pistons are seen other examples of work ground on this machine. Near the left end of the table is a landing gear truck, the flat sides of which must be ground to the same width as the piston lugs and within the same tolerance. The scissors link near the right-hand end of the table is straddle-ground on both the inside and outside surfaces of the yoke bosses, and also on both sides of the opposite end. The limits on this part are plus 0.001 inch, minus nothing.

Form Grinding Operation on Rifle Barrels.—Rifle barrels are ground on irregularly curved surfaces near the breech end, as shown in Fig. 5. The machine used is a hydraulic surface grinder equipped with a special control for the operating cycle of the table and a hydraulic device for form-truing the grinding wheel. The curved surfaces are ground within a tolerance of 0.001 inch at a net production rate of sixty barrels an hour.

Twelve barrels are loaded in the fixture at one time and fed past the grinding wheel by the automatic operation of the machine table. The wheel is fed downward automatically in a plunge cut to a sizing stop. Automatic truing compensates for wear of the grinding wheel and controls the size of the work.

Grinding Sides and Ends of Connecting-rods.—Two quantity production operations on articulated connecting-rods of airplane engines are illustrated in Figs. 6 and 7. The first of these consists of grinding the arms of the rods on both sides after they have been broached. The operation is performed on a surface grinder of the reciprocating table type, as shown in Fig. 6. The rods are loaded in batches of seven on arbors which are slipped through the wrist- and knuckle-

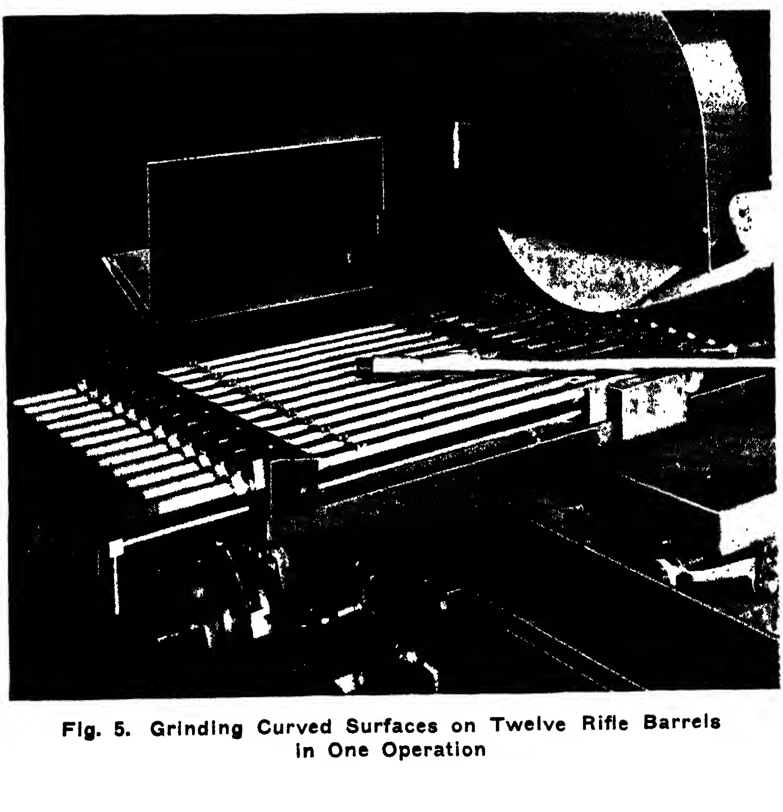

Fig. 5. Grinding Curved Surfaces on Twelve Rifle Barrels in One Operation

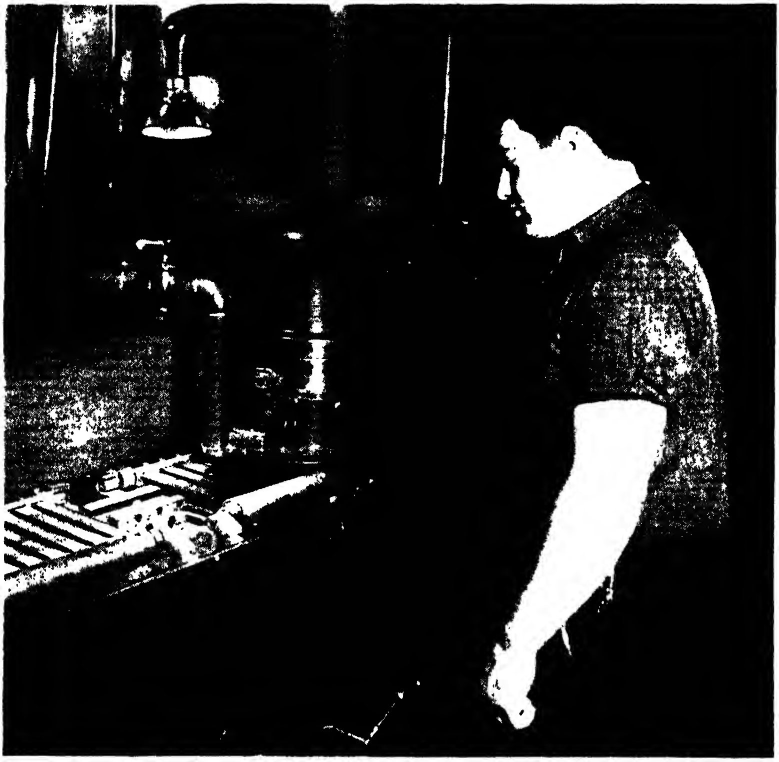

Fig. 6. Grinding the Sides of Articulated Rod Arms, with the Rods Mounted in Batches of Seven on Two Arbors

pin bearing holes. Two batches of seven rods are loaded on the machine at a time for grinding one side of all rods. The rods are then reversed in the fixture without removing them from the arbors for grinding the other side. The arbors are provided with ground ends to insure accurate location in the fixture. The width across the ground arm surface is held within a tolerance of 0.003 inch.

With the articulated rods still mounted on the arbors, they are passed to the grinding machine shown in Fig. 7 for grinding one end to the required contour. This machine is equipped with a fixture that swings the rods back and forth beneath the grinding wheel while they are reciprocated to the right and left with the table. The wheel face is

dressed to the radius of the rod ends. The swinging motion of the fixture is obtained through a separate motor drive and speed reducer seen at the right, which operates a crank and link motion that is connected to the fixture. A diamond dresser at the left-hand end of the table maintains the correct wheel form. When the operation has been completed on one end of the rods, the opposite ends are ground on another machine of the same type, with the rods still being held on the same arbors.

Fig. 7. The Bosses on the Ends of Articulated Rods are Ground to the Required Contour by Using a Form Grinding Wheel and an Oscillating Fixture

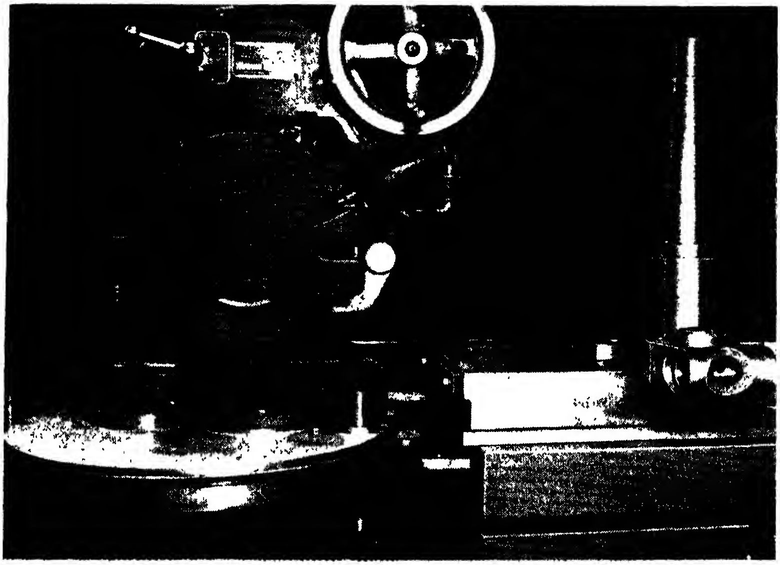

Fig. 8. Hydraulic Surface Grinder Equipped with Both Rotary and Magnetic Chucks

Operations Requiring Reciprocating and Rotary Movements.—Two chucks, one of them of a rotary type and the other a conventional magnetic chuck, are provided on the hydraulic grinding machine shown in Fig. 8, which is employed for grinding surfaces on both cheeks of airplane engine crankshafts. In grinding the flat outer cheek, the shaft portion of the part is inserted in bushings in the rotary chuck, as seen at the left. The operation is then performed by the reciprocation of the regular table of the machine, which carries the work back and forth beneath the grinding wheel. The rotary action of this chuck is used in certain operations, as in grinding part way around a hub, in which case the chuck is oscillated to the right and left.

The magnetic chuck is used for holding crankshafts in grinding flat surfaces on the inside cheek, in which case the work is positioned on the chuck shown at the right. Limits of plus or minus 0.0005 inch are maintained in finish-grinding.

Slot Grinding Operation.—The application of a surface grinding machine for finishing roller slots in the ends of tappets is illustrated in Fig. 9. This machine is equipped with a fixture designed to accommodate twelve tappets. After the tappets have been placed vertically in the fixture. sliding plungers are inserted in holes in the tappets to line them up properly during the tightening of the various clamps. The T-bar is then removed for the operation, during which the slots in the twelve pieces are ground in one traverse past the grinding wheel to a width of 0.250 inch within plus or minus 0.002 inch, and to a depth of approximately 1 inch. The slots were milled in the tappets and the parts heat-treated prior to this grinding operation.

Examples of Work on Machines of Rotary Type.—The surface grinding machine illustrated in Fig. 10 is employed

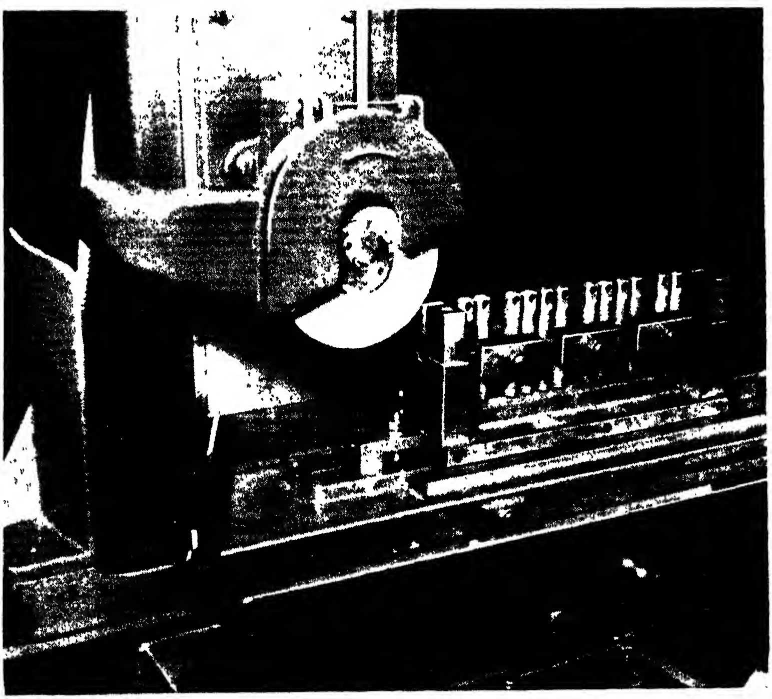

Fig. 9. Grinding Roller Slots in Ends of Tappets, Twelve at a Time

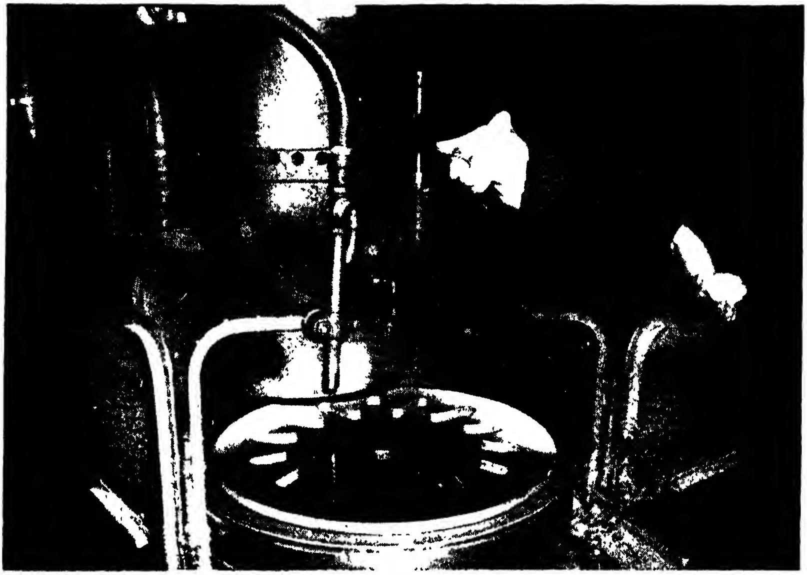

Fig. 10. Finishing Side of Sprocket Wheel for Tank

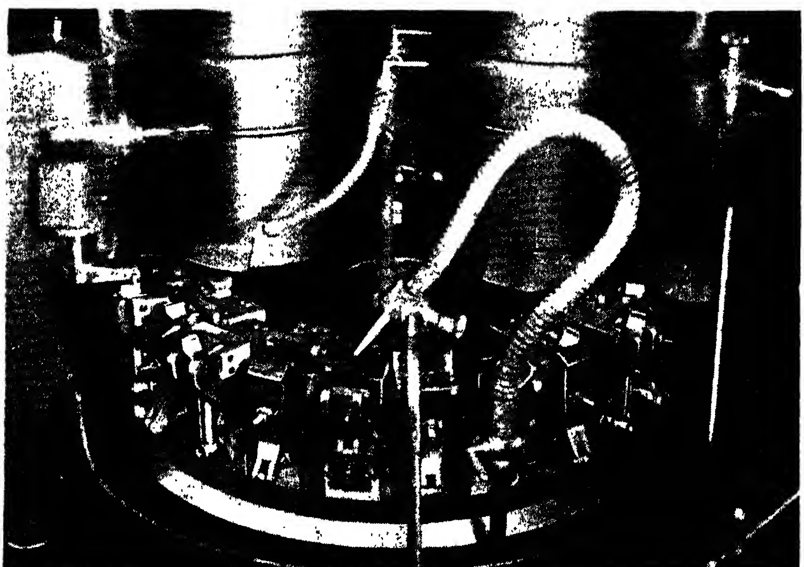

Fig. 11. Grinding Joint Faces of Connecting-rods and Their Caps

for finishing the opposite sides of sprocket wheels. These sprocket wheels, which are for Army tanks, are 27 inches in diameter by 0.8 inch thick. The magnetic chuck is slid in and out by operating a handwheel to bring the work into position beneath the grinding wheel and to withdraw it at the end of the operation.

Connecting-rods and caps are ground on their joint faces at the rate of 550 rods and 550 caps per hour by the surface grinding machine illustrated in Fig. 11, which is in operation in an automobile plant. This machine is equipped with two grinding heads, one for rough-grinding the parts as they are carried beneath it, and the other for finish-grinding them as they return toward the front of the machine. Each head is equipped with an automatic control that insures grinding the parts to a definite size. The roughing wheel generally removes from 0.015 to 0.020 inch of stock, leaving 0.005 inch of stock to be removed by the finishing wheel.

The size of both the connecting-rods and caps is held within plus or minus 0.001 inch; and because the finishing wheel is required to remove only a small and a uniform amount of stock, an unusually smooth finish is attained. The surfaces ground show 90 per cent bearing, or better. when tested on a surface plate.

Application of Indicator Gage and Electric Gage on Surface Grinders.—Fig. 12 shows the grinding of rectangular blocks of steel which are held on the magnetic chuck of a surface grinding machine. These blocks are ground to the required thickness on this machine, after which they are ground on the two edges by another surface grinder of the type illustrated in Fig. 13. The blocks are then cut up to the proper lengths for the production of various parts.

In the operation shown in Fig. 12, five groups of twelve blocks each are ground, sixty in all. At the left is seen an indicator gage, mounted on an arm so that it can be conveniently swung across the top of the work-pieces to determine when they have been ground to the required thickness.

The machine in Fig. 13 is equipped with an electric gage

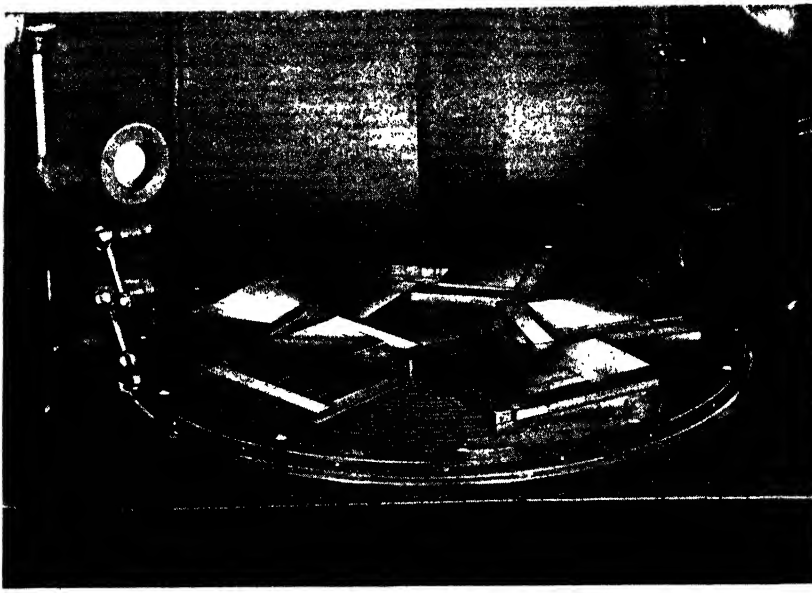

Fig. 12. Grinding Sixty Rectangular Blocks of Steel

Fig. 13. Surface Grinder Equipped with an Electric Gage

that comes in contact with the top of the work-pieces when the grinding wheel has been fed down sufficiently to finish the blocks to the required height. When this occurs, an electric circuit is energized, which rings a buzzer and thus notifies the operator that the parts have reached the desired size. Dimensions are held within 0.0005 inch.

Grinding Airplane Engine Crankcases. — In Fig. 14 is shown a large surface grinding machine finishing the face and hub on the opposite ends of steel crankcases for air-

Fig. 14. A Large Surface Grinding Machine Grinding Surfaces on the Ends of Assembled Airplane-engine Crankcases

plane engines. The platform on which the operator stands is about 4 feet above the surface of the floor and the base of the machine. As the height between the two faces of the work is nominally 23 1/16 inches, the machine had to be constructed with an unusual amount of space between the magnetic chuck and the grinding wheel. The two faces of each crankcase must be ground the specified distance apart within 0.006 inch, but the height between either end face

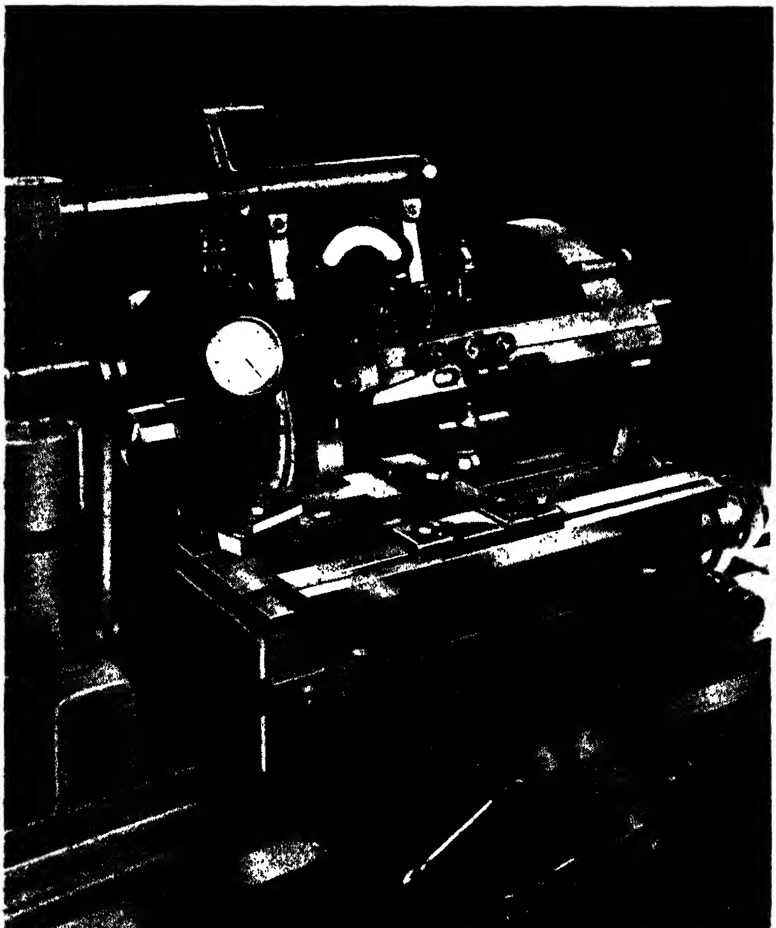

Fig. 15. Machine for Grinding and Lapping Snap Gages

and the corresponding hub face is held to a tolerance of only 0.001 inch. The magnetic chuck is 32 inches in diameter.

Grinding and Lapping Machine for Gages. — A Swiss grinding machine that enables gages to be rapidly ground within close limits is shown in Fig. 15. In the particular operation shown, a snap gage is being ground. When the desired dimension has been reached within close limits, the table of the machine is shifted to the right to bring the gage into line with a lapping wheel mounted on the same spindle as the grinding wheel. The practice is to grind the gages to within 0.0003 or 0.0004 inch of the specified size, and then to lap them within 0.0001 inch of the size without changing the setting of the work.

Suspended from an overhead bar is a unit equipped with a dial indicator graduated to 0.001 inch, and another indicator graduated to 0.00005 inch. Precision gage-blocks are used in setting the measuring fingers of these gages. The measuring fingers are applied to the surfaces being ground or lapped by swinging down the entire indicator unit.

Machine for Grinding Profile Gages.—A machine designed especially for grinding profile gages is illustrated in Fig. 16. The gage to be ground is mounted on a table which can be adjusted longitudinally and crosswise in accordance with observations made through an optical device above the grinding wheel which magnifies the work and the wheel. A large-scale drawing of the profile to which the gage is to be ground is tacked to the table at the left, and a stylus at the end of a pantograph arm is moved along this profile a small amount at a time. The opposite end of the arm is attached to the optical device and causes this unit to swivel over the work each time the stylus is moved.

After each adjustment of the stylus, the gage-maker observes the position of the wheel relative to the work through the optical device and makes corresponding adjustments of the table setting. He then applies the revolving wheel to the work, after which he again changes the setting of the stylus and the work until the gage has been completely ground.

At the time that the photograph was taken, the grinding wheel was set to reciprocate vertically, but it can be set to pass through any desired angular path. The particular gage shown being ground had a circular nose. On the table of the machine is a profile gage of the type for which this machine is more especially adapted. The profile drawings are usually made fifty times the actual size of the gage being ground, so that any error in the gage will be infinitesimal.

Grinding the Flat Surfaces on Hexagonal Nuts. — The flats on hexagonal nuts are ground on the machine shown in Fig. 17 at the rate of 500 an hour for 3/8-inch nuts,

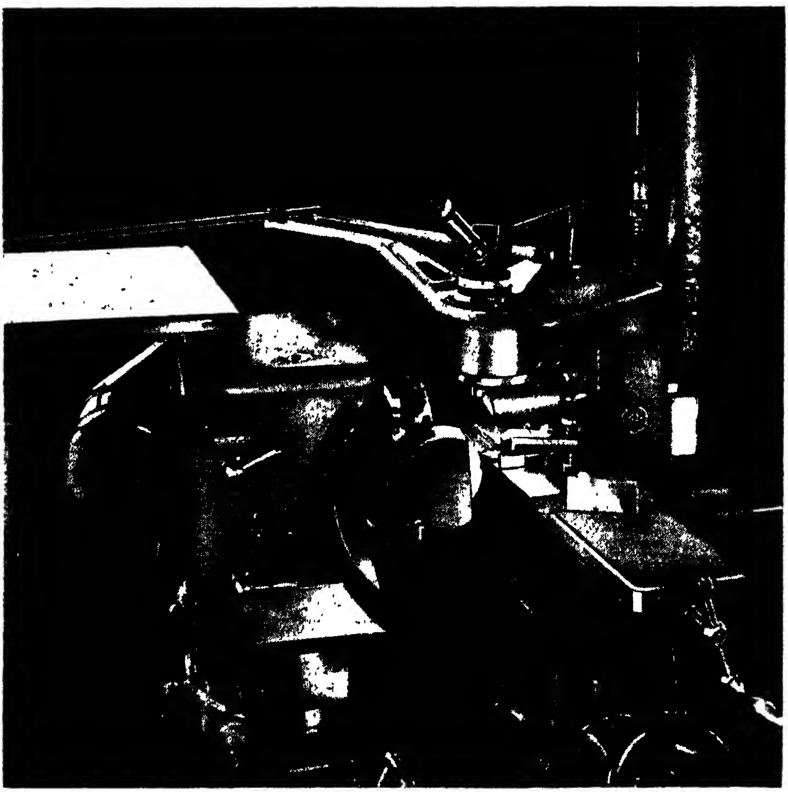

Fig. 16. An Optical Work-setting Device Insures Finishing Profile Gages According to Drawings Laid out Fifty Times Actual Size

and at a somewhat slower rate for the larger sizes. On this machine, the nuts are loaded, four at a time, on pins located between hard steel guides, different pins and guides being provided for the different sizes of nuts. Raising the handle seen in the center of the machine causes the nuts to pass between two grinding wheels, set the proper distance apart. As the handle is lowered, a spring-loaded finger engages a corner of the hexagon and rotates each nut, in turn, through 60 degrees, this rotation being made possible by the fact that one of the guides is hinged and is held in position by spring pressure. The nuts are thus ground on all six sides by three successive passes.

A lever at the extreme right-hand end of the machine

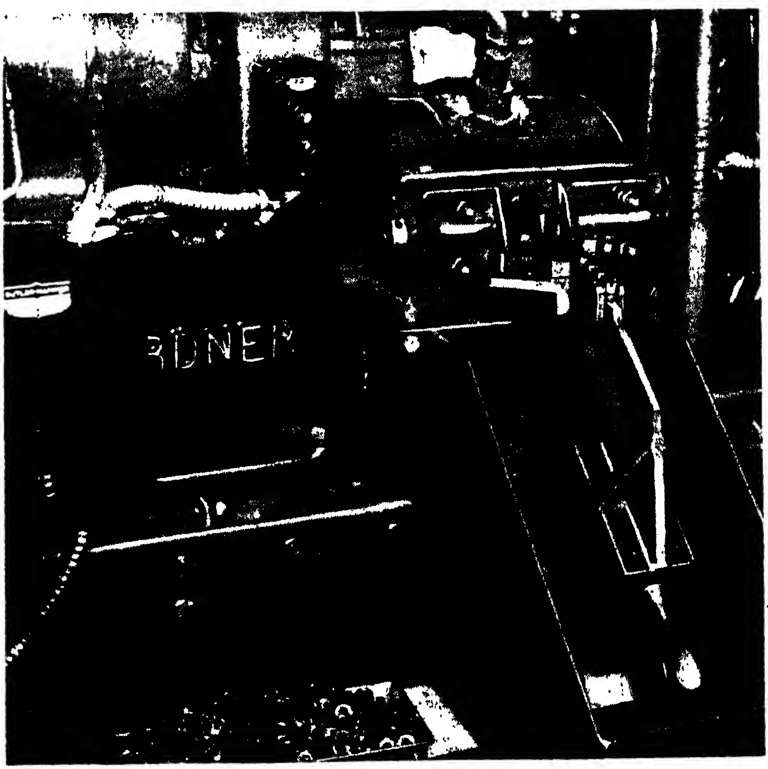

Fig. 17. Double-wheel Grinding Machine which Grinds the Flats on Hexagon Nuts

spreads both grinding heads simultaneously for adjustment and wheel-dressing, an individual fine adjustment being obtained through two graduated dials on the rear of the machine. The wheel-dressing attachment is located at the top and rear of the machine. A handwheel in the center controls the vertical movement of the diamonds across the face of the wheel by means of a rack and pinion, while the hand-knob on the right is used for horizontal adjustment.

Honing and Superfinishing Processes

The hone-abrading process is applied to the cylindrical surfaces of cylinder bores or other parts requiring extreme precision, and also to some external cylindrical surfaces. In honing, several desirable results are combined in the process. These include: (1) Generating a true cylindrical form by the rapid economical removal of metal necessary to eliminate whatever inaccuracies may have remained from a previous or preliminary machining operation; (2) obtaining a true cylindrical form of given diameter within extremely small dimensional limits; (3) securing a final surface finish of practically any desired quality or degree of smoothness needed for precision work.

The honing tool contains abrasive stones or "sticks" which vary as to width, length, and thickness. These abrasive stones, as applied to a cylindrical bore, are expanded to bear evenly against it with a pressure that is varied to suit requirements. The honing machine imparts combined rotary and reciprocating motions to the hone which is self-centering in the bore. A true cylindrical form is generated by these combined motions in conjunction with positively controlled expansion and equalized pressure of the honing tool. The cutting action of the hone is also under control to secure required surface quality. Honing tools may be actuated either mechanically or hydraulically.

The amount of metal removed by honing varies for different classes of work and also depends upon the accuracy of the preceding operation. For example, from 0.001 to 0.003 inch may be removed from a ground hole; 0.003 to 0.005 inch from a reamed hole, and 0.005 to 0.010 inch from a bored hole. These figures are merely by way of

Fig. 1. Honing Machine Employed for the Reconditioning of Cylinder Assemblies for Radial Aircraft Engines

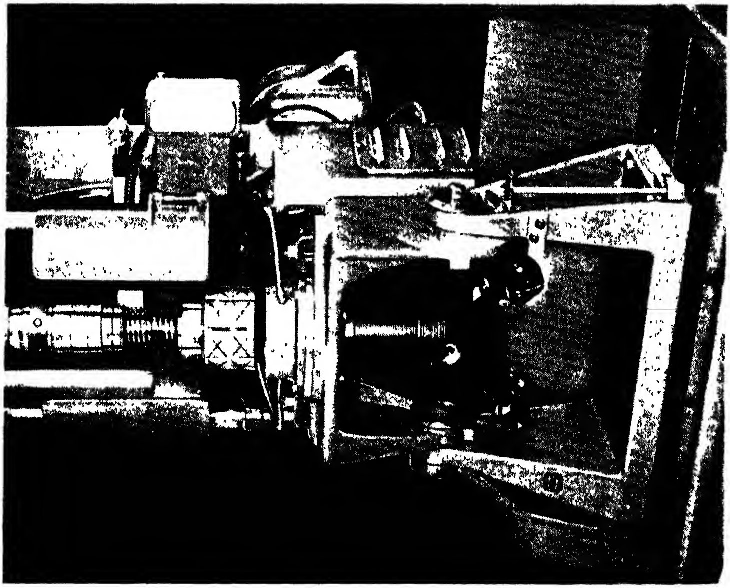

Fig. 2. Another View of Machine Seen in Fig. 1 Equipped with Cast-iron Laps which are Used after Finish-honing

illustration, and much larger amounts can be removed readily when necessary. In some classes of gun barrel honing, as much as 65 cubic inches of material have been removed per hour in correcting, sizing, and finishing the bore. The surface speeds in honing may range from 10 to 250 feet per minute, depending upon the amount of stock to be removed and the final finish desired. An ample and continuous supply of clarified coolant should be furnished in honing. The kind of coolant depends upon the material to be honed.

Honing Airplane Engine Cylinder Barrels.—In Fig. 1 is shown a close-up view of a machine equipped for honing cylinder barrels. This machine is so designed that the operator can control the number of spindle revolutions during a dwell period of the hone at the blind end of the bore for the purpose of removing all excess stock and obtaining a straight cylindrical bore. Cap-screws are used to hold the flange of the cylinder assembly against the top plate of the fixture. The fixture can be tilted as shown for reloading, a drop-in pin being used to lock it in the working position, as illustrated in Fig. 2.

Badly worn cylinders are honed without any correctional regenerating operation such as grinding. As much as 0.015 to 0.020 inch of out-of-roundness and taper have been corrected in reconditioning operations within an accuracy of 0.0003 inch. The stock removal ranged from 0.010 to 0.025 inch on the diameter.

Some engineers in the aircraft industry maintain that all processing marks in newly finished bores should be parallel longitudinally, it being claimed that this permits the closest possible mating of surface irregularities on moving parts and on the cylinder wall. The advantage of such a condition would be the minimizing of oil consumption and blow-by on initial runs. Considerable effort has, therefore, been directed toward developing a method of obtaining this type of finish.

Fig. 2 shows a machine equipped with a straight-line lapping tool for this purpose, this tool being used in a third operation after rough- and finish-honing. Cast-iron

laps are mounted in conventional stone-holders and impregnated with an abrasive paste. A stroking motion only is imparted to the tool, provision being made for indexing it in such a way that each tool is made to overlap its previous path. Approximately twenty-five indexings are necessary for one complete rotation of the tool. The laps have a tilting or rocking action in the stone-holders and are thus free to seat themselves against the walls of the bore.

Finishing Drilled Holes by Honing.—Holes which were previously drilled through the lugs of the main and nose struts of a hydraulic landing gear for airplanes, are finished by honing in order to insure a tight fit of the assembly bolts and to remove all tool marks. This operation is performed by the machine shown in Fig. 3, which is equipped with a fixture that slides crosswise of the machine to locate the two sets of lugs in line with the hone. The sliding member of the fixture is made with an inclined

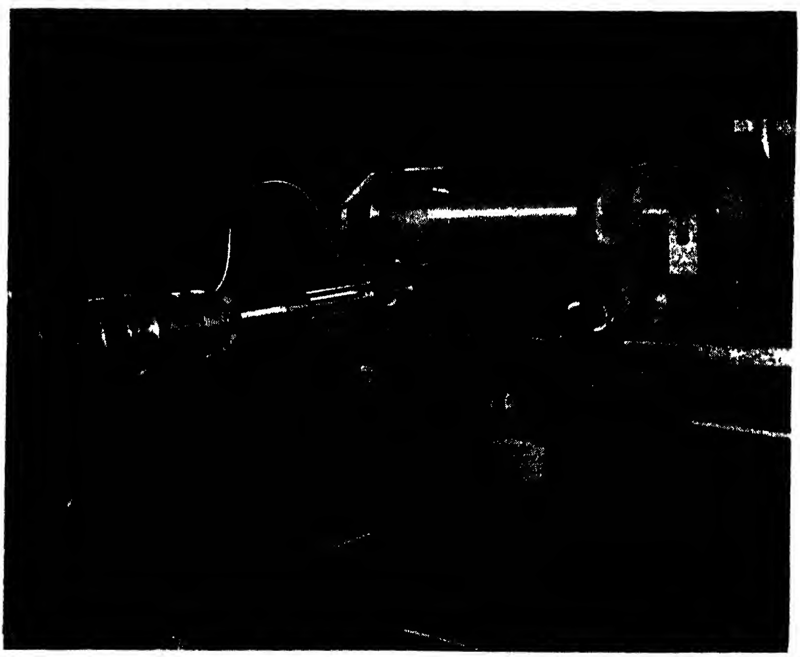

Fig. 3. Honing Bolt Holes in an Airplane Landing-gear Part

surface to compensate for the difference in the distance from the center line of the strut to the center of the two lug holes. The hone is made with four abrasive stones. It finishes the lug holes to the specified dimensions within 0.0005 inch in one operation, during which from 0.001 to 0.0015 inch of stock on the diameter is removed. A similar operation is performed on the cross-bore holes of the landing-gear pistons.

While the main and nose struts or cylinders are produced from swaged tubing, the pistons that operate in them are machined from solid forgings. At the left in Fig. 4 may be seen one of the rough piston forgings and a finished piston. These pistons are made of chromium-molybdenum steel. They are first drilled to a diameter of 2 inches, after which a core drill 3 1/4 inches in diameter is employed to open up the hole to the closed end. This hole is then rough- and finish-bored within a tolerance of

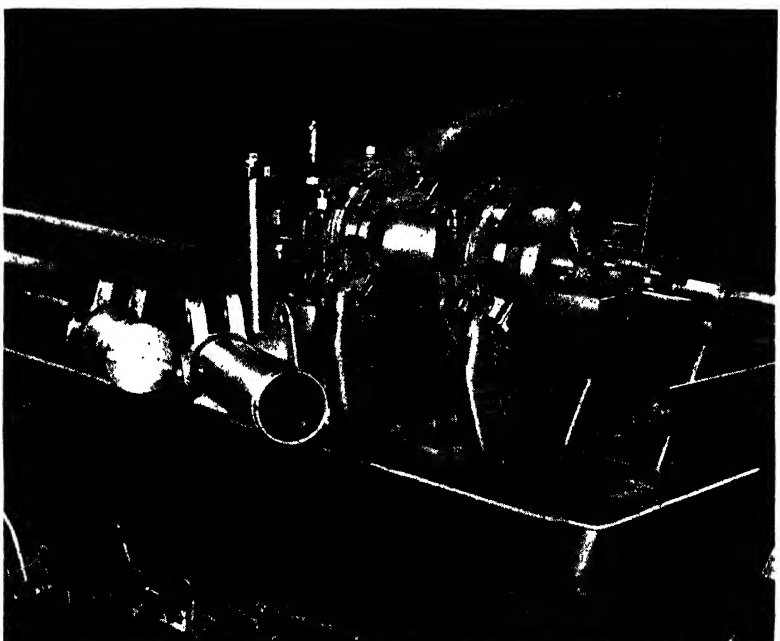

Fig. 4. Honing a Strut Piston on a Machine of the Hydraulic Type

0.003 inch, and rough- and finish-honed. The drilling, boring, and honing operations are all performed on machines of the type shown by the illustration.

Honing Cylinders of Gun Recoil Mechanism.—In Fig. 5 is shown a horizontal hydraulically operated machine used for finishing three cylinders in the recoil mechanism cradle for a 155-millimeter gun. The three bores have nominal diameters of 7.500, 5.375, and 3.3125 inches, and must all be honed within a tolerance of 0.0008 inch for the entire length of 92 1/4 inches. Two of the cylinders must be parallel to the cradle ways within 0.0001 inch.

Rough-, semi-finish-, and finish-honing are performed. In the roughing step, from 0.005 to 0.010 inch of stock is removed on the diameter; in semi-finish-honing, about 0.0015 inch is removed; and in finish-honing not more than 0.001 inch. The finish-honed surface must have a smooth-

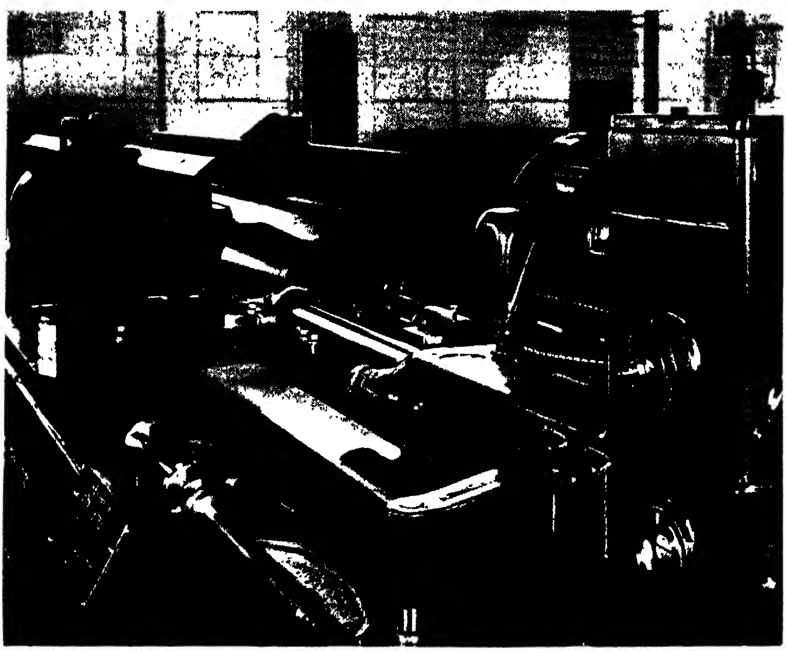

Fig. 5. Machine Used for Honing Three Cylinders in the Recoil Mechanism Cradle for a 155-millimeter Gun

ness within 6 to 8 micro-inches. Later the bores are machine-lapped longitudinally to a smoothness of 4 micro-inches. In the honing operations, a coolant consisting of oleic acid, kerosene, and turpentine gives especially good results, as it eliminates crumbling of the abrasive stones.

Rough- and Finish-honing Three Bores. — The machine shown in Fig. 6 is used for honing three diameters in each main and nose strut of an airplane landing gear. Rough- and finish-honing are performed on all three bores by this machine. The tool-head is arranged to reciprocate under the close control of hydraulic valves that are operated by switches. At the front end of its stroke in honing one bore, the hone must stop against a shoulder. From 0.005 to 0.006 inch of stock on a side is removed in rough-honing, and about 0.0005 inch of stock in finish-honing. A mixture of kerosene and International honing compound is applied to the hone, and the latter is constructed with six abrasive stones. The purpose of this honing operation is to obtain a mirror finish on inside surfaces, entirely free from minute tool marks that might develop into cracks when the strut is in service.

Honing Anti-aircraft Gun Barrels. — The hydraulically actuated honing machine illustrated in Fig. 7 is honing anti-aircraft gun barrels. This machine is constructed with a bed at one end on which there are brackets fitted with bearings to receive the barrel and hold it with the bore in direct line with the honing bar. A honing tool equipped with four stones is employed in this operation. About 0.022 inch of stock on the diameter is removed to bring the bore to size within 0.04 millimeter or approximately 0.0015 inch and also straight for the full length within 0.002 inch.

At the end of the honing operation, a ground plug gage, 15 inches long and only 0.0012 inch smaller in diameter than the honed bore, must be passed through the full length of the bore. If a bore is not straight within very close limits, this plug will bind. The diameter of the bore is checked every 3 inches of length by means of a gage provided with registering points which are applied both vertically and horizontally in the bore.

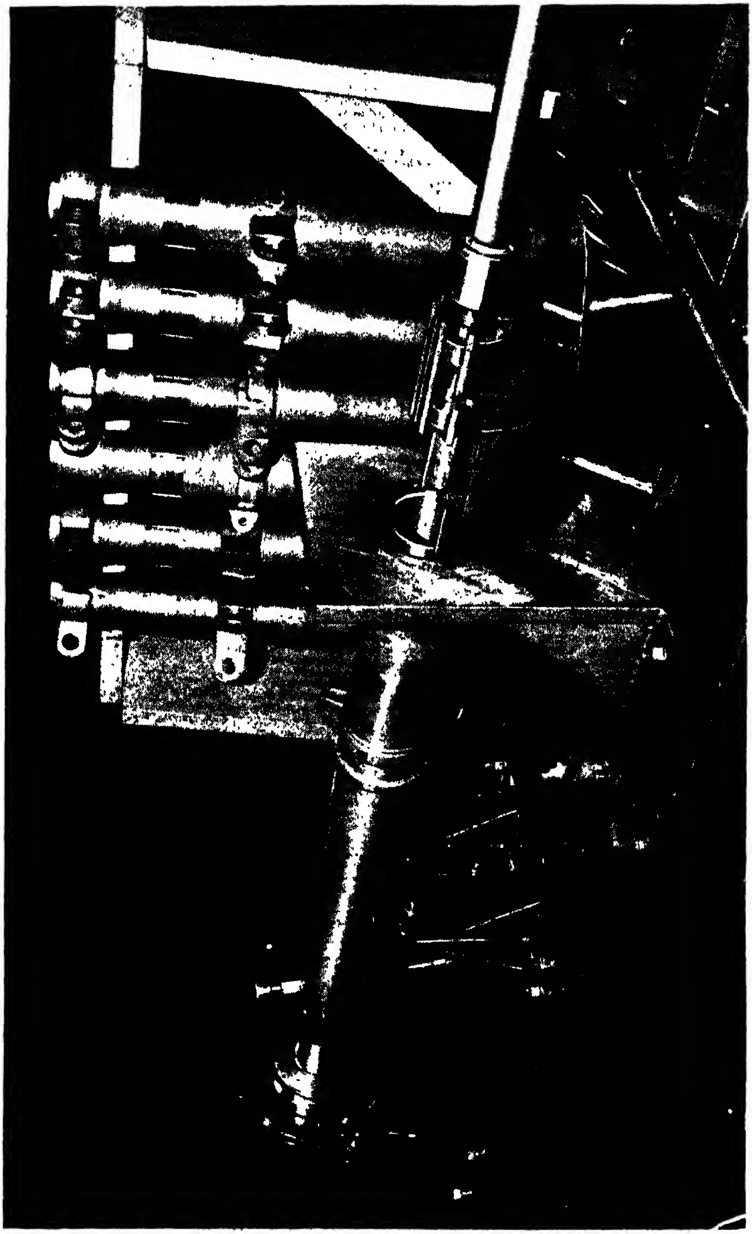

Fig. 6. Three Bores in Each Main and Nose Strut of Airplane Landing Gear are Rough- and Finish-honed

After the barrel is clamped in the brackets, 0.020 inch of stock on the diameter is rough-honed from the bore. The barrel is then placed on the floor to cool, and later the remaining 0.002 inch of stock is honed out to obtain the finished size. A compound consisting of 90 per cent of lard oil and 10 per cent of kerosene has been found unusually satisfactory for this operation. The floor-to-floor time is generally 2 3/4 hours, including inspection.

Honing Recoil Cylinders. — The recoil cylinders for 75-millimeter guns, which fit into the bores of the trunnions, are bored, reamed and then honed. These cylinders must be finished to extremely close tolerances as to taper and diameter. For this reason, accuracy in boring is of utmost importance. This operation is performed on a turret lathe that is equipped with five reamer bars. The bar

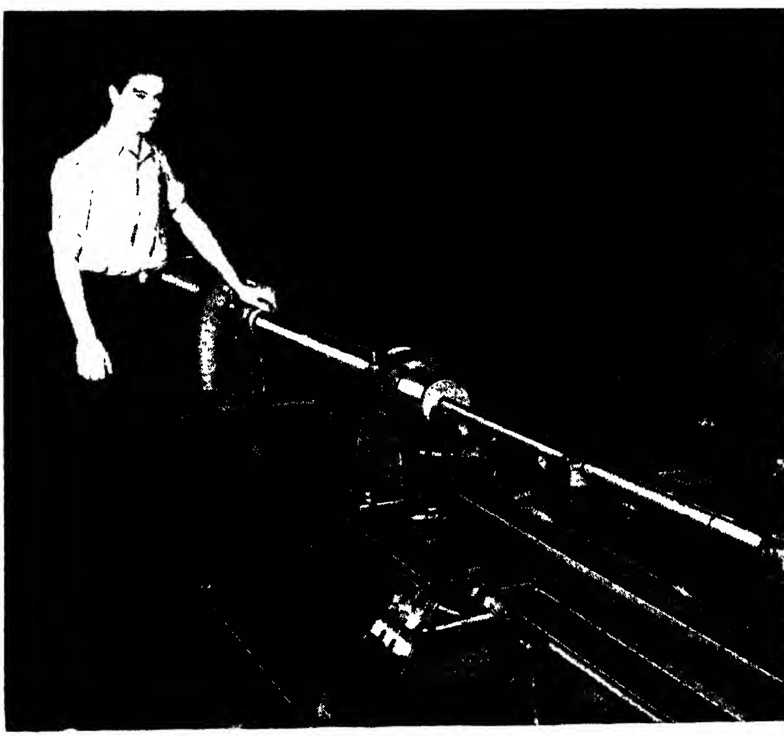

Fig. 7. Honing Bore of Anti-aircraft Gun

in the first turret station is provided with a single blade cutter for taking a rough boring cut the full length of the cylinder. The second bar is provided with two cutters for finishing two steps in the cylinder. Reamers on the next three bars finish the two internal diameters prior to honing. All five tool bars on the turret are equipped with pilots 20 inches long by 3 inches in diameter which engage a bushing in the center of the headstock spindle to insure straightness of the cylinder bore for its full length.

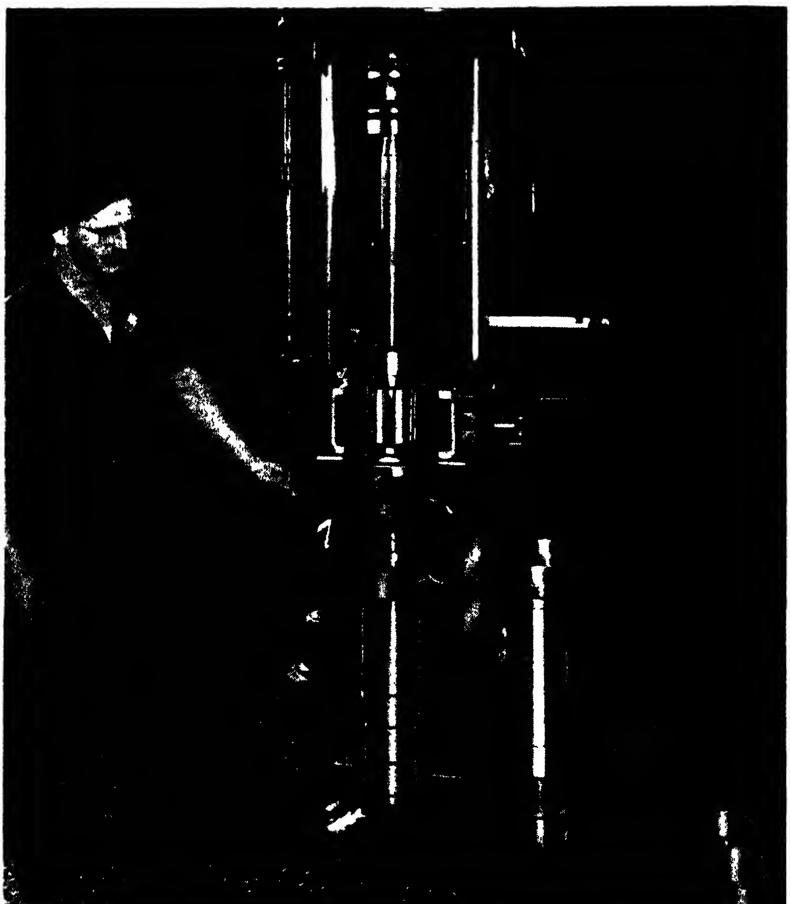

Fig. 8. Honing Recoil Cylinders for 75-millimeter Guns

The honing operation is performed on the vertical machine shown in Fig. 8. This machine is supplied with a fixture that slides in and out on the base so that the cylinders can be quickly reloaded without the necessity of raising the hone higher than the position shown. When the cylinders leave this machine the bore must be straight the full length of 30 inches within 0.001 inch and it must be to the specified diameter within plus 0.002 inch, minus nothing. The accuracy is checked with an Electrolimit gage.

Example of External Lapping.— The piston-rods for the recoil mechanism of a 155-millimeter gun are first honed and then lapped. In honing, the honing head floats in a fixed position in the center of the bed of the honing machine, and the work both revolves and reciprocates through the hone. Being mounted in a floating holder, the hone is free to follow slightly curved rods. The hone is adjustable for diameter, but is of such a design that the abrasive stones are held solidly after being adjusted. Separate heads are used for rough- and finish-honing. There are six abrasive stones in each head.

From the external honing operation, the piston-rods are taken to the duplex hydraulically operated lapping machine shown in Fig. 9. In this operation, two heads with either stones or wood blocks 1 1/4 inches wide are reciprocated along the work. The piston-rods are indexed at each end of the stroke until they have been lapped completely around their circumference. With steel piston-rods, an abrasive stone is used for rough-lapping and a wooden block with a fine abrasive compound for finish-lapping. Piston-rods of Monel metal are lapped with a fine paper under the wood blocks. All together, from 0.0002 to 0.0008 inch of stock on the diameter is lapped off, just enough to remove the cross-hatch lines produced in honing.

Superfinishing Operations. — The expression "superfinish" indicates a surface finish of exceptionally fine quality obtained by a special process. The finish is produced by stones, which are comparatively hard and of medium grit and operate with a "scrubbing action." The object in super-

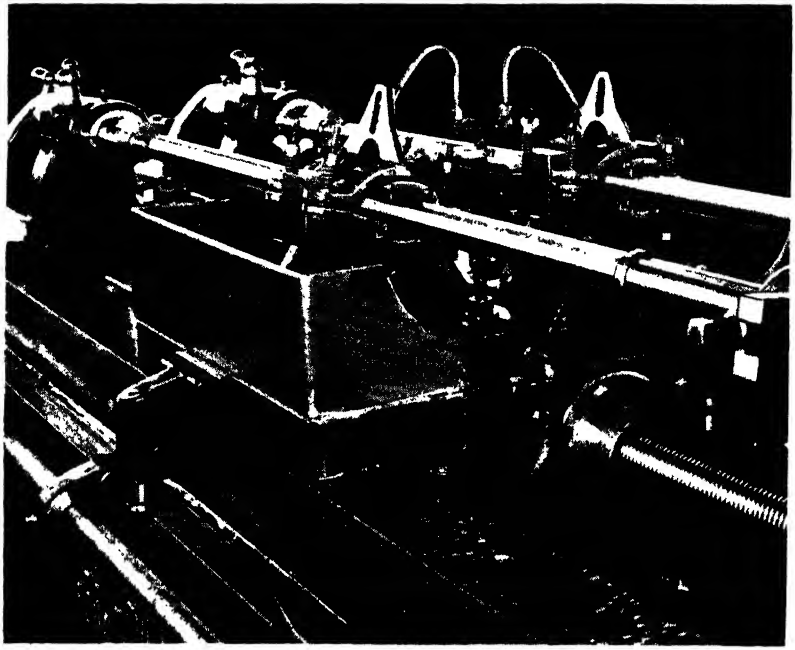

Fig. 9. Lapping Two Piston-rods Simultaneously in a Machine that Reciprocates the Laps and Indexes the Rods

finishing, as in honing, is to eliminate minute scratches and surface defects created by previous mechanical operations and produce a bearing surface in which any remaining scratches will be below the mechanically made bearing surface.

In the process, ordinary abrasive stones of proper grain and hardness, acting in a suitable lubricant and under sufficient pressures progressively applied, are brought into contact with the metal surface to be superfinished. At least three motions are required to produce superfinish and five or more are desirable. Equipment is in use that has as many as ten motions operating simultaneously. As the result of this multi-motion scrubbing with abrasives, the superfinished surface need have no indentation deeper than a few millionths of an inch. This process may be used in finishing flat, round, concave, convex, and other surfaces.

The finish is obtained mechanically and the machines used vary in design to suit the shape and size of the work.

Machines for superfinishing may be designed for a given class of work or for general application. A general-purpose superfinisher may be applied to cylindrical parts in a range of diameters and lengths. This machine is being used for a wide variety of processes. It is adapted for superfinishing leader pins for die sets, cylindrical gages, draw-mandrels, pump pistons and shafts that pass through packing, motor armature shaft bearings, bearings on small crankshafts, etc. Superfinishing machines for general application to flat surfaces have also been developed.

Superfinishing heads for lathes are mounted on the compound rest of an engine lathe cross-slide. With this arrangement, practically any cylindrical work within the

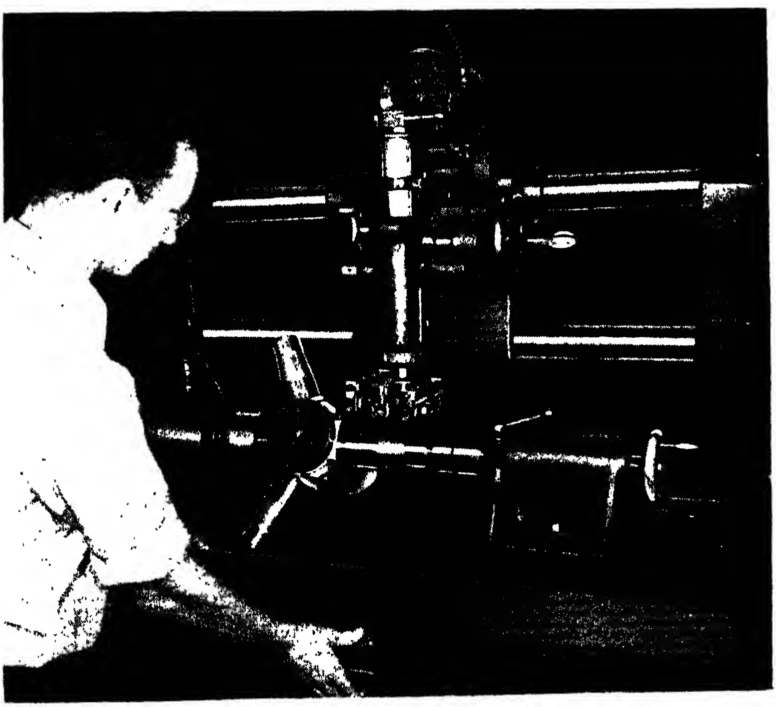

Fig. 10. Bearings of Propeller Spider Arms are Given a High Degree of Finish in This Superfinishing Machine

capacity of the lathe can be superfinished. Special heads can also be made for boring mills, grinders, and other machinery. The superfinishing heads have a wide range of uses.

Superfinishing Spider Arms of Airplane Propellers. — In the plant of a prominent manufacturer of propellers, one

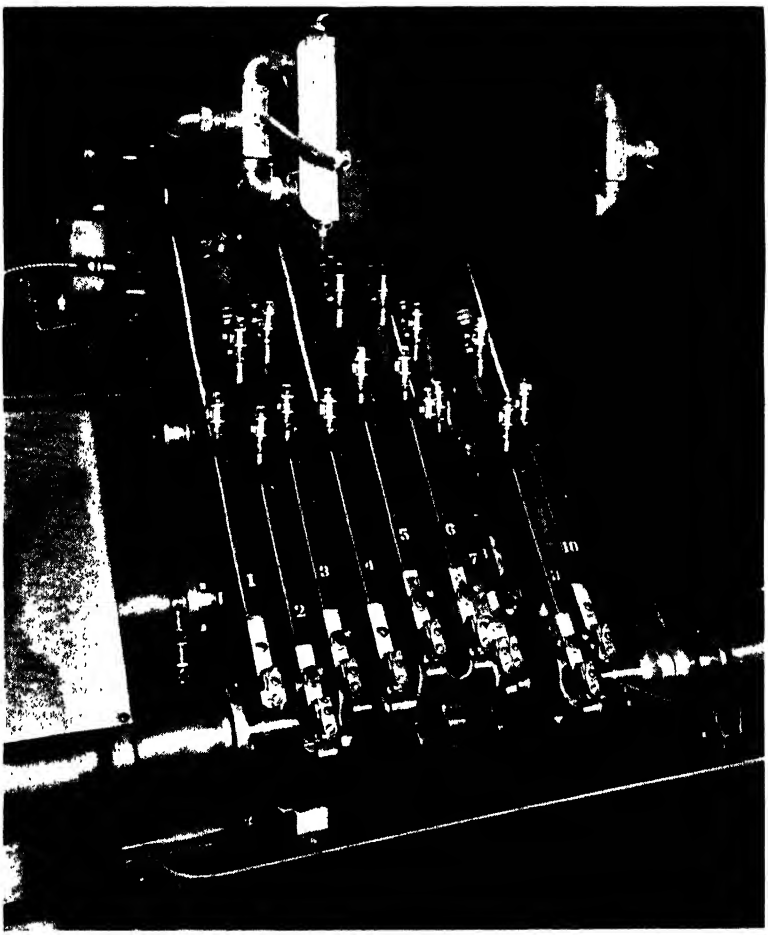

Fig. 11. Superfinishing Machine which Imparts the Final Finish to All the Main Bearings and the Crankpins of Automobile Crankshafts Simultaneously

of the final operations on the spiders consists of superfinishing two bearings on each arm. This operation is performed on the machine illustrated in Fig. 10. The part is revolved slowly between the centers while the two-stone abrasive head is oscillated in a horizontal plane, with one stone riding on each bearing. The abrasive stones are free-floating in all directions.

Superfinishing Automobile Parts.—The finishing of machined surfaces by superfinishing is now applied in automotive and other plants on a quantity production basis. In one large automobile plant, crankshafts, pistons, and camshafts are all superfinished in sufficient quantities for supplying the great number of cars produced every day. A view of a crankshaft superfinishing machine is illustrated in Fig. 11. This machine superfinishes all of the main and crankpin bearings simultaneously. When the crankshafts leave this operation, the superfinished surfaces have a smoothness within 6 and 7 micro-inches, which is equivalent to between six and seven millionths of an inch.

Examples of Gear-Cutting and Gear-Tooth Finishing

In the manufacture of machines of various classes, the production of satisfactory gearing has been one of the important problems, especially where speeds are high and noise must be reduced to a minimum. The problem has been solved by the development of gear-cutting and gear-finishing machines in conjunction with precision equipment for checking and controlling the accuracy of various elements affecting gear operation. A few miscellaneous examples of gear-cutting are included in this section.

Hobbing Herringbone or Double-helical Gears.—A typical hobbing operation is shown in Fig. 1. These particular gears are used for large rolling mill drives. On wide-face gears, the teeth are of the staggered herringbone type, the inner end of each tooth being in line with a space between two opposing teeth. The advantages claimed for teeth of this type are unusually good distribution of the load and easy flow of the lubricant from tooth to tooth. With the staggered teeth, there is a continuous zig-zag channel through which the oil can readily flow when the gears and pinions are running in mesh. Single helical teeth are hobbed on gears of narrow face. Gears up to 15 feet in diameter are handled on the machine shown, although the gear seen on the table is only about 8 feet in diameter.

In setting up a gear for the tooth-hobbing operation, the accuracy of the set-up is determined by revolving the gear at a fast speed in contact with a dial indicator attached to the hob slide. Similar readings are also taken on the finished bore as a double check. Adjustments are made until the gear face and bore run true. The teeth are

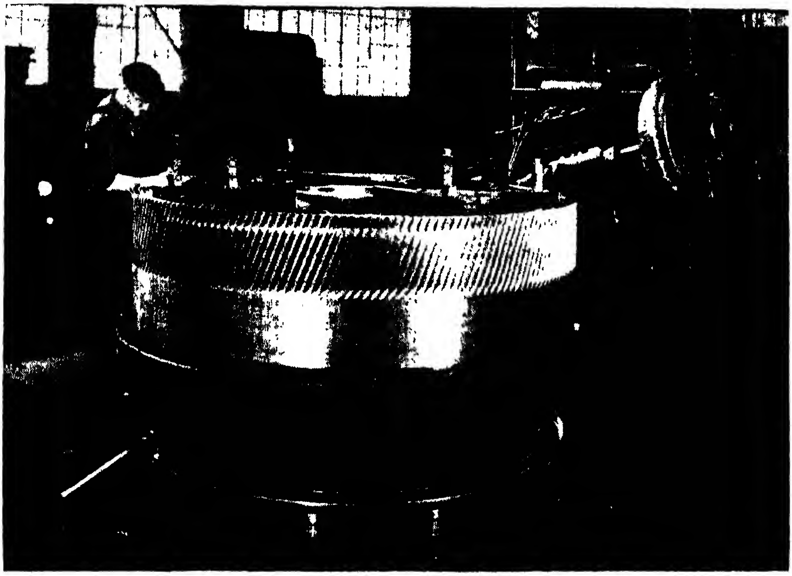

Fig. 1. Hobbing One Side of Herringbone Gear

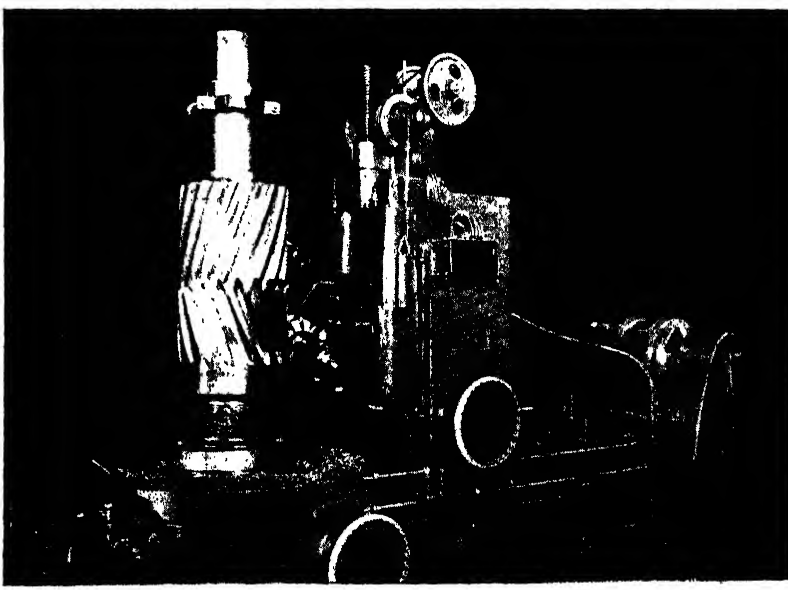

Fig. 2. Rough-hobbing Herringbone Pinion

next roughed out on one side of the face, as seen in the illustration; the gear is then turned over on the machine table and again carefully checked for true running, after which the teeth are roughed out on the second half of the face.

The gear rotation is then checked again to see whether the stresses produced in the boring operation are causing the gear to revolve eccentrically, the run-out being held to not more than 0.008 inch. After the necessary adjustments of the work have been made and the hob changed, finishing cuts are taken on the gear teeth, the same procedure being followed as in roughing. When a finishing cut has once been started on a gear, the machine is not shut down until the operation has been completed, even though many hours are involved, because it is practically impossible to avoid producing a slight step on the gear teeth when a machine is started again after having been stopped in the midst of an operation.

A hook-tooth hob is used for roughing, and a standard hob of ground-tooth form for finishing. On coarse-pitch teeth of, say, 1 1 2 or 1 diametral pitch, a single-thread hob is employed, and on teeth down to 3 diametral pitch, a multiple-thread hob is used. A cutting oil is applied copiously to the hob and work during these operations.

In hobbing the pinion teeth, the pinion blank is mounted vertically on the machine table, as shown in Fig. 2, with the journal at the lower end rigidly supported in a split chuck. As in hobbing the gears, the pinion teeth are first roughed out on one half of the face, and then, after the pinion has been changed end for end in the chuck, the teeth on the opposite side are roughed out. The pinion is also checked for true running of the journals at the beginning of the operation, and at the end of the roughing, adjustments are made for any eccentricity caused by stresses created during the roughing cuts.

The teeth are then finish-hobbed. Both the finished gear and pinion teeth are checked for width at the pitch line and for variations between the teeth by a vernier gear tooth caliper.

Turbine Reduction Gears Cut in Air-Conditioned Rooms.— Reduction gears for the steam turbine drives of ships must be machined to extreme degrees of accuracy in order to obtain successful operation at the customary high rates of speed. The gears mounted on propeller shafts range up to 12 feet in diameter and run at speeds as high as 400 revolutions per minute. The pinion in the reduction train may run as fast as 6000 revolutions per minute. Double-helical gears of this large diameter are produced with the pitch diameter accurate within plus or minus 0.002 inch. Of even greater importance to gear performance than accuracy of pitch diameter is correctness of the helix angle of the gear teeth, uniform tooth spacing, and correct tooth contour. Satisfactory turbine gears are the result of maintaining the tooth-cutting machines and their hobs in as nearly perfect condition as possible. The machines should be thoroughly checked at frequent intervals to make certain that the bearings, worm-gearing, and lead-screw are in first-class condition, so that they do not introduce errors into the tooth-cutting operation. Similarly, the elements of all hobs used in cutting the gear teeth should be inspected frequently.

Even with first-class machines and tools, however, certain precautions must be observed during the manufacturing stages to produce satisfactory gears. One important precaution is to maintain uniformity of the operating temperature, because changes in the room temperature will cause inaccuracies in the helix angle of the different teeth, with the result that all the teeth in the finished gear will not come in contact with the full width of the teeth on the mating pinion. Changes in the temperature are also likely to result in an "out-of-round" pitch circle.

The cutting of the teeth on large turbine gears may be a matter of weeks, and is performed day and night without stopping the machine, except to change the hob for the finishing cut after the roughing of the teeth has been completed. In cutting a gear of the size seen in Fig. 3, for example, approximately eighteen days are required for roughing the teeth and seven days more for finishing them.

Uniform temperature throughout the cutting of reduction gears has been made possible in the shop selected as an example, by the erection of heat-insulating walls and ceilings over the individual gear-cutting machines to form rooms in which an even temperature can be maintained during the entire period of gear-cutting. Cooled air is supplied to these rooms in the summer by refrigerating apparatus, and heated air in the winter. The practice is to maintain the temperature in the rooms at 70 degrees F., although the exact degree is not important so long as the temperature existing at the beginning of the operation is maintained to the end. Recording thermometers produce records of any temperature changes throughout the oper-

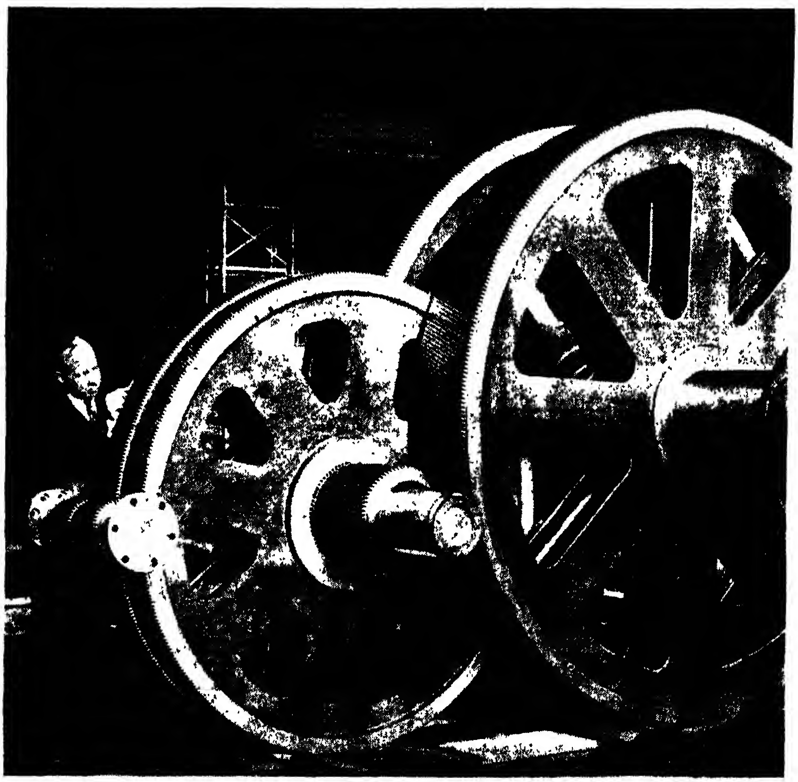

Fig. 3. Double Reduction Gearing for a Marine Turbine Drive

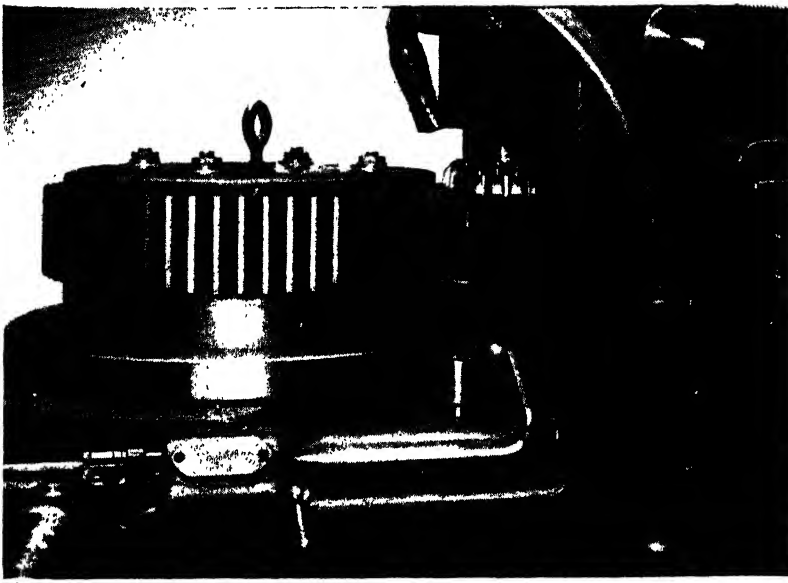

Fig. 4. Cutting a Tractor Gear on Gear Shaper

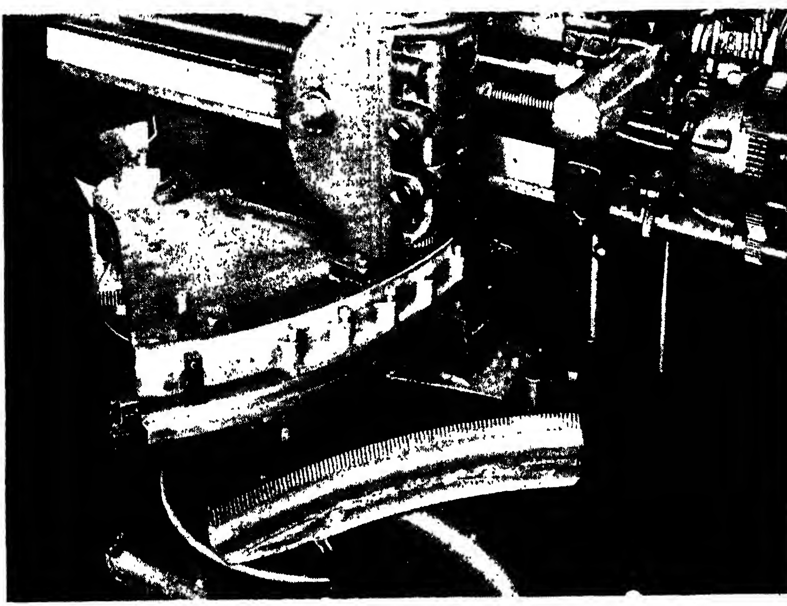

Fig. 5. Cutting the Teeth around a Segment

ation, and these records are filed for future reference.

At the end of the tooth-hobbing operation, all gears are balanced dynamically. When light weight is required, gears are made of welded steel construction, as seen in Fig. 3, although many gears are made with cast-iron centers and steel rims shrunk and keyed to the centers.

Example Showing Application of Gear Shaper.—Large bull gears for tractors are being cut on the gear shaper illustrated in Fig. 4, which has capacity for gears up to 40 inches in diameter by 8 inches face width and 2 diametral pitch. The gear shown in the illustration is about 28 inches in diameter. The work-table of this machine is provided with a fast traverse for moving the work rapidly toward and away from the cutter, and for approximately positioning the work in relation to the cutter. A feed-cam is employed for the depth feed, which operates independently of the lead-screw used for the rapid traverse. The feed-cam controls the depth of cut per stroke of the cutter through change-gears. Upon the completion of a gear, an air cylinder returns the work-table to the starting position.

Cutting Internal Gears with Gear Shaper.— In the operation illustrated in Fig. 5, internal teeth of 12 diametral pitch are being cut around a bronze gear segment within a tooth spacing tolerance of 0.001 inch. The operation is performed on a gear shaper equipped with a special fixture, pivoted at the center of the segment, which is about 30 inches from the teeth. This fixture is geared to the regular table mechanism for obtaining the necessary generating movements. Three cuts are taken on the gear teeth.

Fig. 6 shows a gear shaper cutting internal teeth in an automobile clutch drive-gear. A gear blank is seen at the left front of the machine. The gear shaper is used extensively for internal (as well as external) gears because it provides an accurate and efficient method of forming the teeth.

Finish-cutting of the teeth on a ring gear having forty-

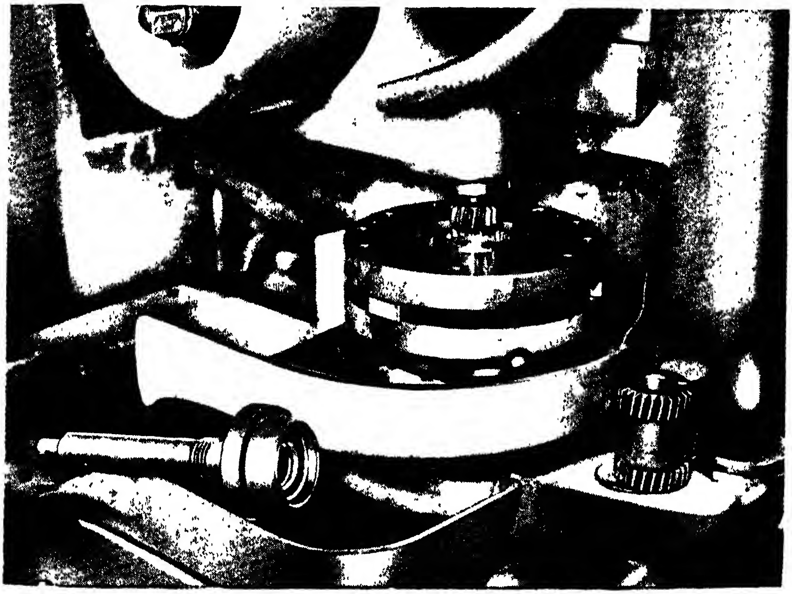

Fig. 6. Cutting Internal Teeth in a Clutch Drive-gear

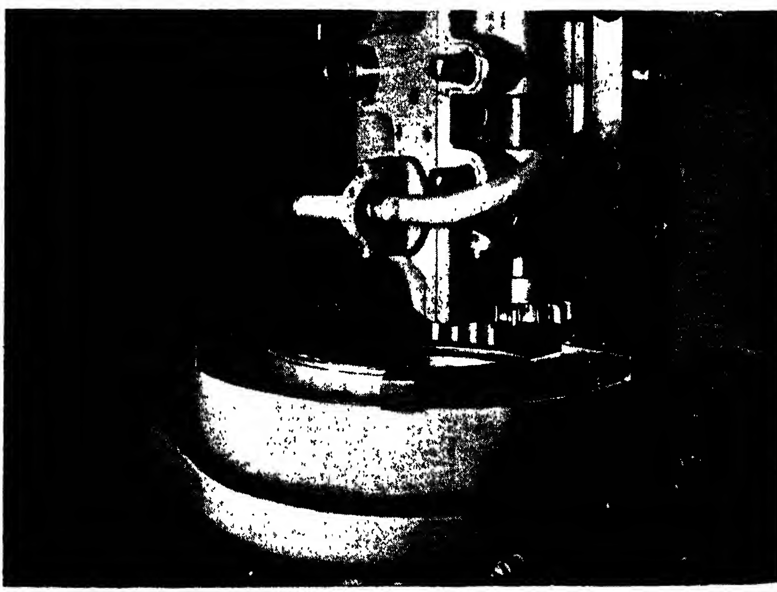

Fig. 7. Finish-cutting a Ring Gear

four teeth of 3 1/2 diametral pitch is illustrated in Fig. 7. This operation, as well as that of gashing the teeth, is performed on a gear shaper equipped with a fixture designed to insure accurate loading of the work and retaining of the cutting oil.

Cutting Internal Gear by Milling Process.—Internal gears up to 92 inches in diameter are milled on the machine in Fig. 8, which is equipped with a special tool-head. The cutter-spindle is driven through helical gears on each side of the cutter, to which power is transmitted from the main drive of the machine. In a typical job the tooth spacing between any two teeth must not vary more than 0.004 inch. The gear blank is mounted in a circular fixture which is provided with vertical grooves accurately milled around the periphery for indexing purposes. In indexing, a pin

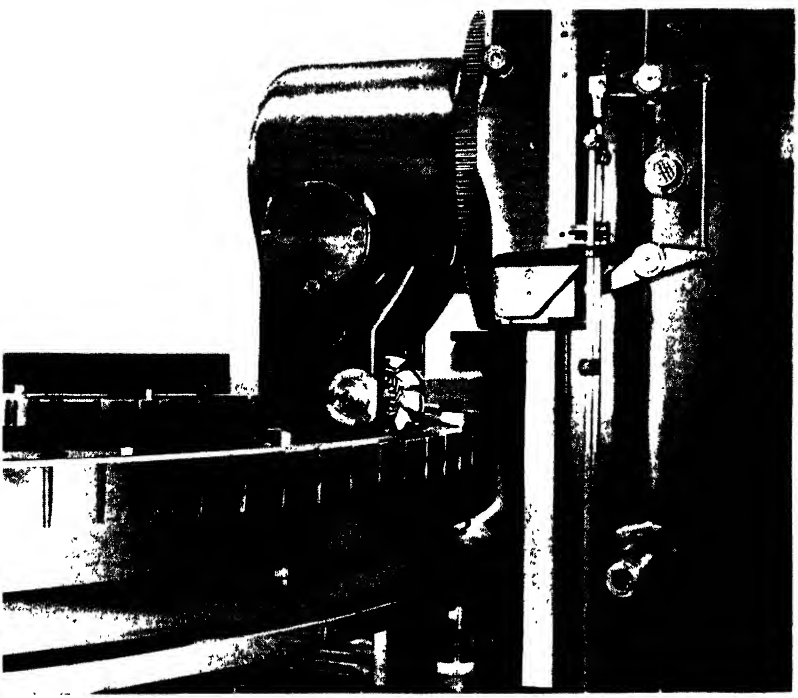

Fig. 8. Special Cutter-head for Cutting the Teeth of Internal Gears up to 92 Inches Pitch Diameter

on a slide attached to the rear side of the machine column is entered into one of these grooves and a reading taken on the pin by means of a dial gage to determine the accuracy of the setting.

Cutting Large Gears on Gear Planer of Templet Type.— Large spur gears of coarse pitch may be cut either by planing on a templet or form-copying type of machine, by milling with a formed cutter, or by hobbing. Most gear manufacturers use the templet planer for the very large gears. One advantage of this type of machine is that simple, inexpensive tools are used, and this is very important, as often only one of these large gears is required, and the cost of making a formed cutter or hob would be prohibitive. Gear-cutting machines of the templet type are also used for cutting large spur, bevel, and herringbone gears; in fact, gear planers of this class are used invariably for cutting very large bevel gears. Some gear planers are designed for cutting spur gears exclusively, but there are also combination types which may be applied to either spur or bevel gears.

A characteristic feature of the templet planer is the templet or master former which serves to guide the planing tool, thus causing it to plane teeth having the correct shape or curvature. When the planer is at work, a slide or head which carries the tool is given a reciprocating motion as the tool feeds inward. This type of machine may be applied to both external and internal spur gears. The large machine shown in Fig. 9 is cutting an internal gear. The faceplate of this machine is 33 feet in diameter, and gears somewhat larger than this can be accommodated. The internal gear being machined at the time that the photograph was taken was about 10 feet in diameter. Gear teeth can be cut with a circular pitch up to 3 1/2 inches.

The teeth are planed by the reciprocation of a tool-head that is actuated through an eccentric crank. The bed on which this tool-head is mounted can be moved across the front of the faceplate on wide floor ways which are normally kept covered by a wooden platform. Accurate indexing of the gears to insure proper spacing of the teeth is

accomplished through an indexing gear about 15 feet in diameter back of the faceplate.

Cutting Large Spiral-bevel Gears.—Spiral-bevel gears up to 60 inches in diameter may be cut on the large machine shown in Fig. 10. The pinions to be cut are mounted on the end of the work-head opposite to that on which the gears are mounted, the work-head being swiveled on its base to suit. In cutting the gears and pinions, a stocking cutter is first employed to rough out the bulk of the mate-

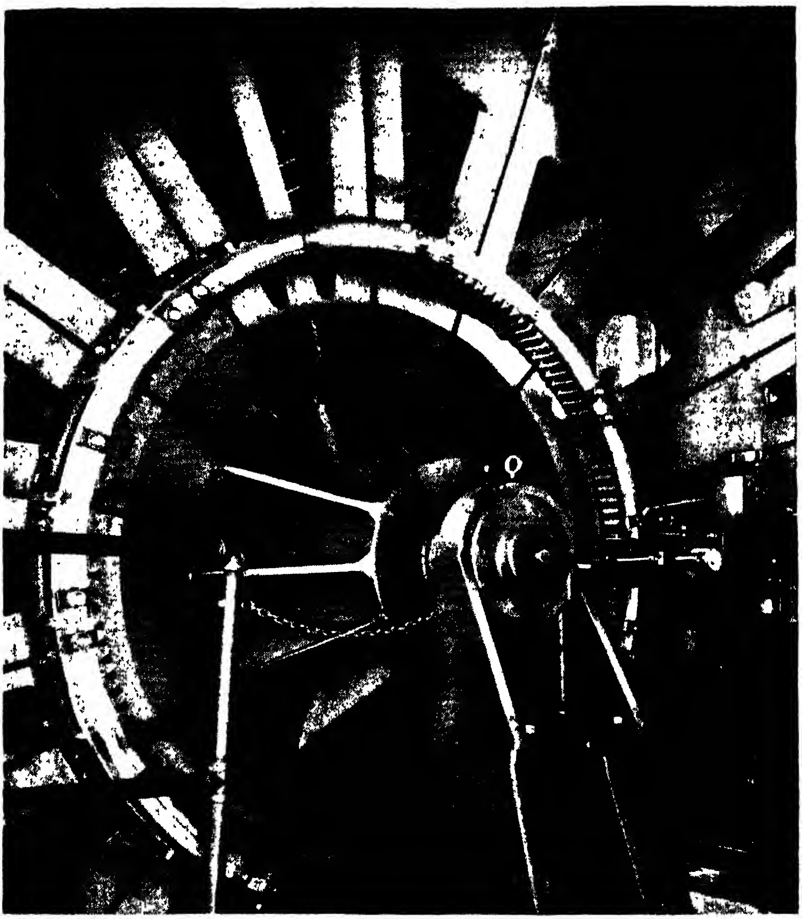

Fig. 9. Cutting Large Internal Gear on Planer of Templet Type

rial, after which semi-finishing and finishing cuts are taken. The gears are not removed from the machine until they are completed, but the pinions are taken off after roughing, to facilitate machining them in quantities.

The spiral bevel gears and pinions are then tested in pairs in the shop where this machine is installed, by running them together with and without load. Loads are applied by a brake on the driven work-spindle. Before this test the gear and pinion are matched for center-to-center distance so as to obtain the desired tooth contact. Prussian blue is applied to the gear and pinion teeth in order to check the contact area on all teeth.

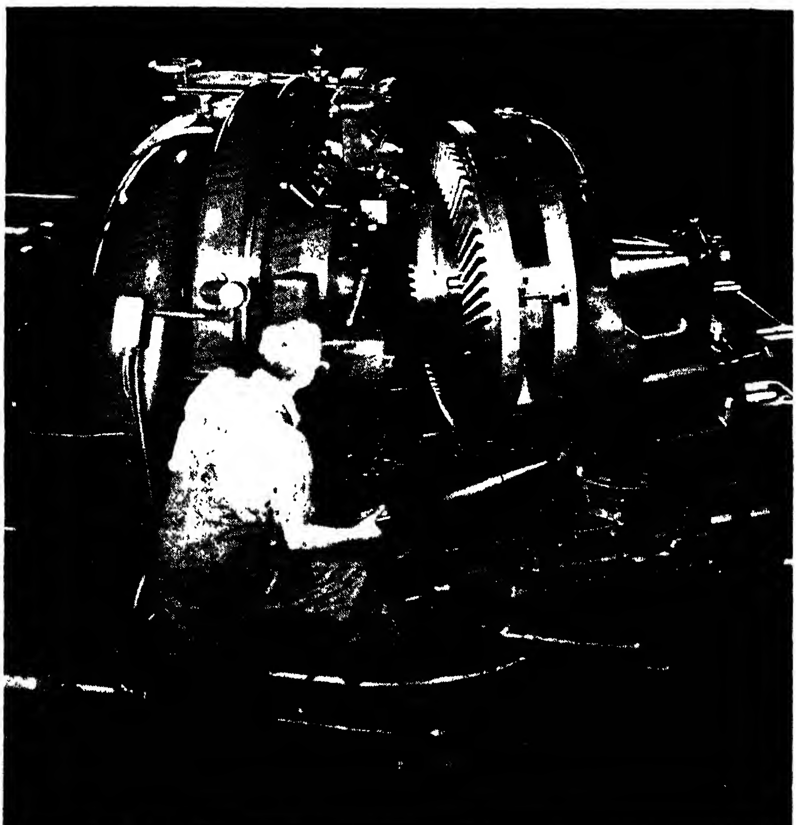

Fig. 10. Cutting the Teeth of a Spiral Bevel Gear

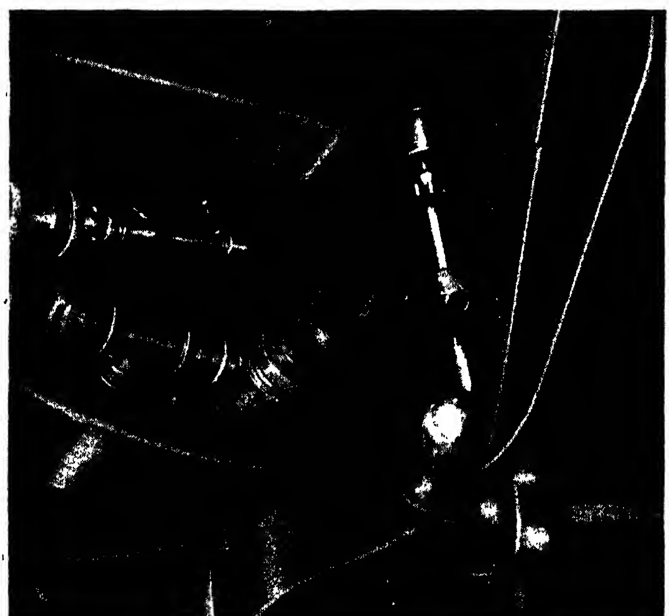

Fig. 11. Grinding Teeth of Spur Gears on Two-wheel Type of Machine

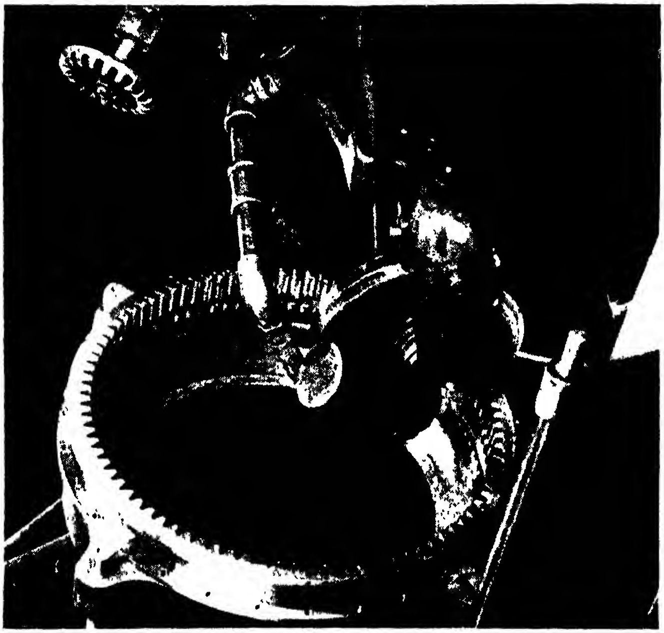

Fig. 12. Grinding Teeth of Internal Gear by Formed-wheel Method

Grinding Teeth of Spur Gear.— An example of gear-tooth grinding is shown in Fig. 11. This two-wheel hydraulic gear-tooth grinder is equipped with wheels 20 inches in diameter. One side of each wheel is dressed to a cone corresponding to the flat-sided basic rack that is the origin of the involute system. Thus, the desired involute curve is ground on the teeth as the gear is rolled back and forth beneath the two wheels through the action of a master rack and gear at the front of the machine. The adjacent sides of two teeth are ground simultaneously. Each time that the gear rolls out of engagement with the grinding wheels it is indexed for the next reciprocation.

The practice is to remove from 0.004 to 0.006 inch of stock from each side of the gear teeth in three or four complete indexings of the gear beneath the grinding wheels. The gear shown being ground has thirty teeth of 7/9 diametral pitch. Gears of a greater width than 1 1/4 inches and splines of the involute type are ground on single-wheel machines in this shop. The gear-tooth grinders are all equipped with filters for the coolant.

Grinding Teeth of Internal Gear.— The grinding of two rows of teeth in the large internal gear of a speed reduction unit is performed as illustrated in Fig. 12. The wheel is dressed to the profiles of two adjacent teeth, so that the sides of two teeth are finished as the wheel is reciprocated across the gear. The practice is to take several rough-grinding cuts around the gear and then a finish-grinding cut. The wheel is dressed several times during rough-grinding and also prior to finish-grinding.

Chamfering Ends of Pinion Teeth.— In Fig. 13 is shown a machine that is employed for removing the burrs from the top and bottom ends of the pinion teeth. Two fly cutters, mounted on separate shafts, remove the burrs as they revolve in synchronism between the teeth of the rotating pinion. Proper location of the pinion teeth in relation to the cutters is insured by the application of a locator at the front of the fixture which is swung upward into engagement with two of the pinion teeth. With the locator in

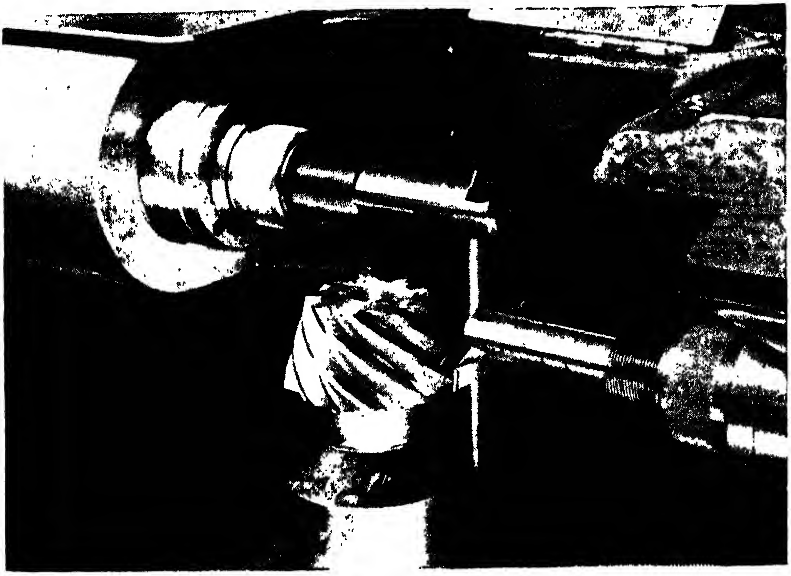

Fig. 13. Chamfering Machine for Removing Burrs from Ends of Pinion Teeth

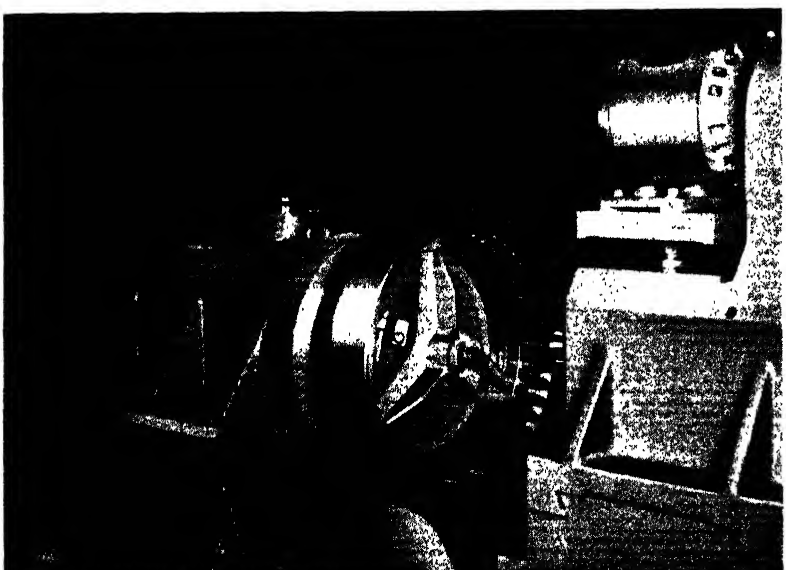

Fig. 14. Rounding Teeth of Ring Gears Along Front and Rear Edges

position, the operator depresses a foot-pedal to actuate a hydraulic valve for clamping the pinion securely. The locator is then lowered out of the way. In the operation, the cutter-head feeds forward automatically to bring both cutters into the operating position, and returns when the pinion has completed one revolution.

Rounding the Teeth of Ring Gears.—The teeth of ring gears are rounded both along the front and the rear of the profiles by the machine shown in Fig. 14. In this illustration, the tool is shown being applied to the rear ends of the teeth. In rounding the teeth at either the front or back, the tool remains in one position while the gear revolves and, at the same time, moves back and forth, as well as sidewise, to keep the changing contour of the teeth against the cutter. The movements of the work-head are derived from cams. The ground bore of the gear is gripped securely on a hardened and ground ring by a three-arm clamp operated by hydraulic pressure.

Cutting Helical Gear on Thread-milling Machine.—The method of cutting small helical gun-control gears illustrated in Fig. 15 is unique, the operation being performed in a thread milling machine, as two shoulders on the part are too close to the helical gear to permit hobbing in the customary way. In fact, a gear-cutter of special diameter is required on the thread milling machine to avoid cutting into the shoulders. In producing the helical teeth, a roughing cut is taken within 0.002 inch of the finished depth and the remaining stock is removed in a second cut with the same set-up. The helical gear on the part shown has four teeth of 12 normal diametral pitch and a spiral angle of 45 degrees. When ground, the outside diameter of this gear must be 0.998 inch within plus 0.0005 inch, minus 0.002 inch. Both the helical and bevel teeth are polished after hardening. The tolerance across pins placed in the helical teeth is 0.0007 inch.

Methods of Finishing Gear Teeth.—When very precise gears are required, as in the automotive, aircraft, and certain other industries, special gear-tooth finishing machines

are used. There are several different types. One type takes a very light shaving cut to correct errors left by the gear-cutting machine. The general practice is to semi-finish the gears on some generating type of gear cutter and then use a finishing machine. A lapping operation may also be applied to gears which, prior to heat-treatment, were finished on a machine of the shaving type. This dual finishing process is applied when extreme precision is essential. A third type of gear-finishing machine operates by rolling the gear to be finished in contact with a master burnishing gear. In using a shaving type of machine, the cutting action may also be accompanied by more or less burnishing, depending upon the angular position of the cutting tool as explained later. Finishing methods have been developed for different classes of gears, such as ex-

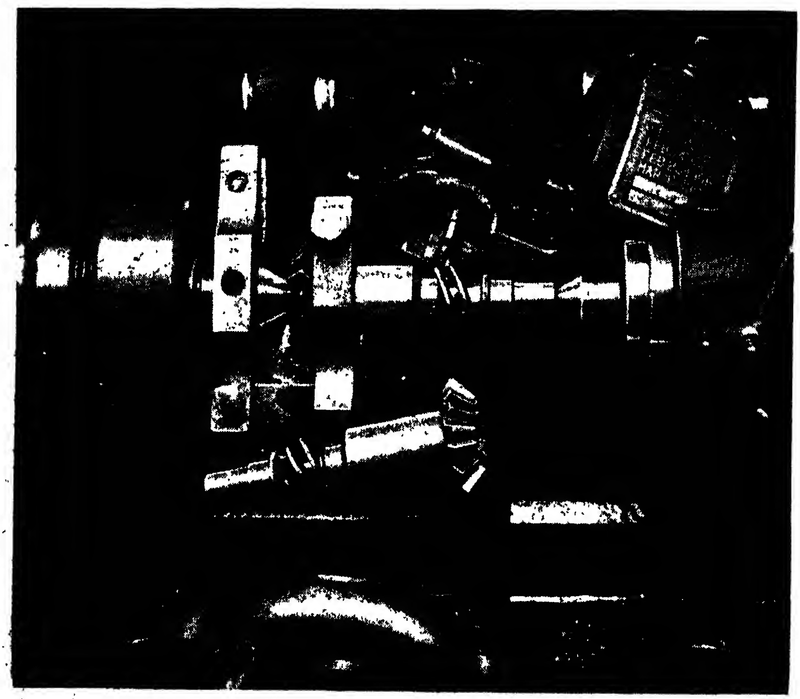

Fig. 15. Cutting the Teeth of a Small Helical Gear on Thread Milling Machine

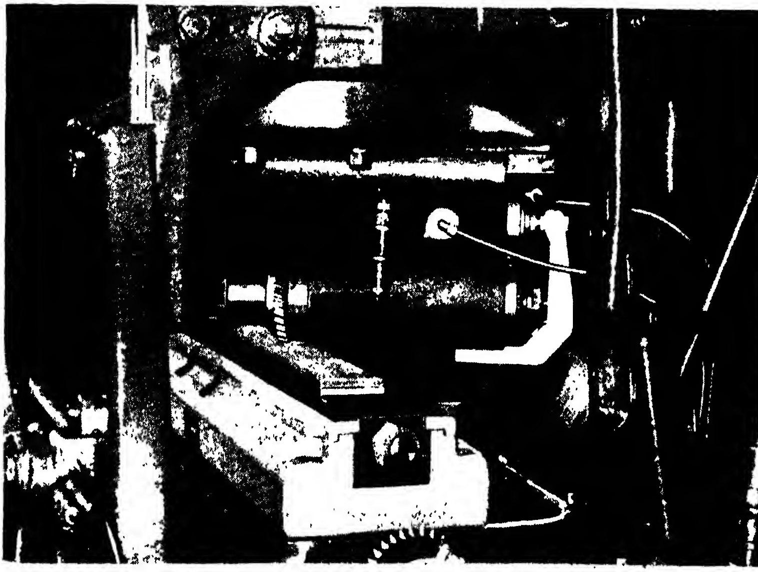

Fig. 16. Gear Shaving Machine Equipped with Special Work-head Designed to Eliminate Mounting Flat Gears on Arbors

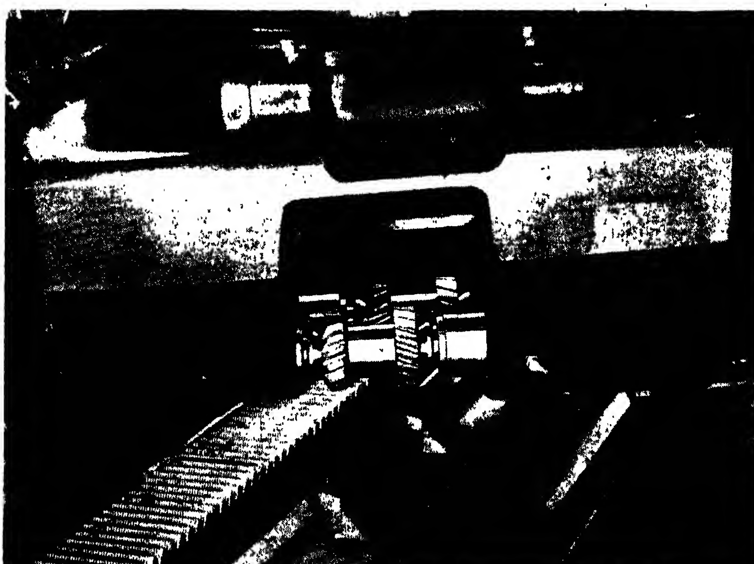

Fig. 17. Gear Shaving Machine with Special Work-head that Enables Two Gears to be Shaved Simultaneously

ternal and internal spur and helical gears, bevel gears, spiral-bevel gears, and hypoid gears.

Finishing Gear Teeth by Shaving Method.—A special work-head for a gear shaving machine, designed to facilitate the handling of first-and-reverse transmission gears, is illustrated in Fig. 16. On a standard machine of this type, it is necessary to mount flat gears of the kind shown on an arbor, which is held between centers above the shaving rack. It was to eliminate the work involved in loading the gears on the arbor that the special work-head was designed.

This head is provided with a stub arbor, on which the work is slipped, as shown, and then a collar with a bayonet lock is placed on the end of a bar that extends the full length of the stub arbor and projects from the front end. The work is quickly clamped through the operation of an air cylinder located in the work-head directly above the stub arbor when air is admitted into the cylinder to actuate a yoke connected to the rear end of the bar on which the collar has been placed. Accuracy is insured not only by the seating of the broached hole in the gear on the stub arbor, but also by the location of the finished face of the gear against a shoulder on the arbor. With this method of handling the work, one man can operate two machines.

Another gear shaving machine equipped with a special work-head is illustrated in Fig. 17. This head is designed to enable two reverse idler gears to be shaved simultaneously. The two gears are loaded into the teeth of the shaving rack and positioned endwise against two live stub centers in the rear (stationary) end of the work-head. Then an air valve is operated to advance the two live stub centers into the front end of both gears. The entire head is adjustable crosswise of the shaving rack to enable the work to be correctly positioned.

Finishing Gear Teeth by Lapping.—In Fig. 18 is shown a machine for lapping gear teeth, the gear being revolved between three cast-iron laps to which abrasive compound is applied. The laps are each 7 inches in diameter, the

Fig. 18. Lapping Gears for Automobile Engines

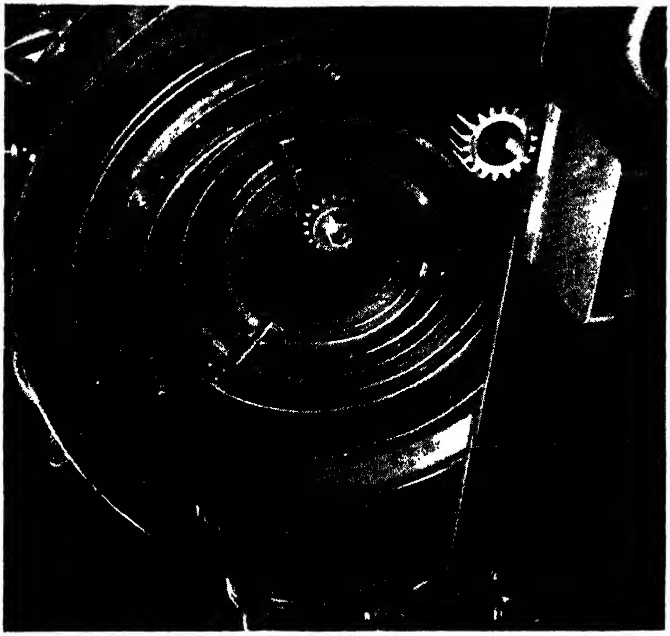

Fig. 19. Another Type of Gear Tooth Lapping Machine

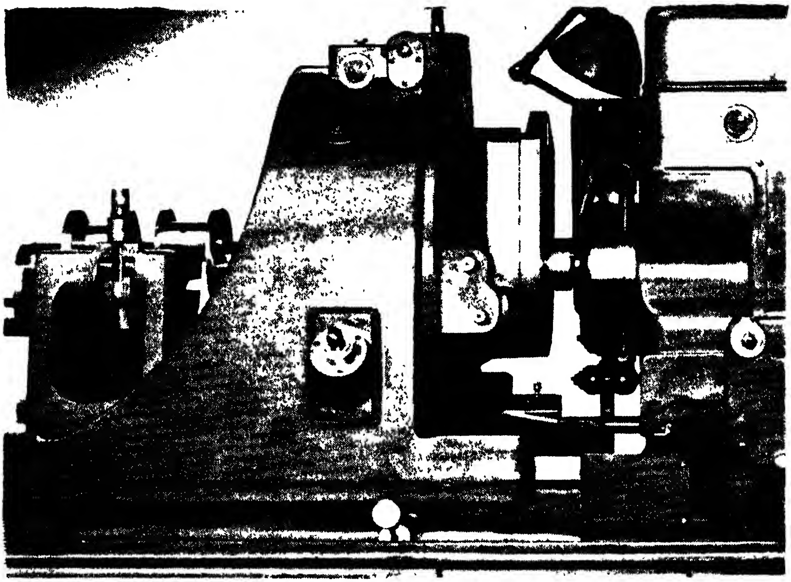

Fig. 20. Cutting Splines with Horizontal Type of Gear Shaper

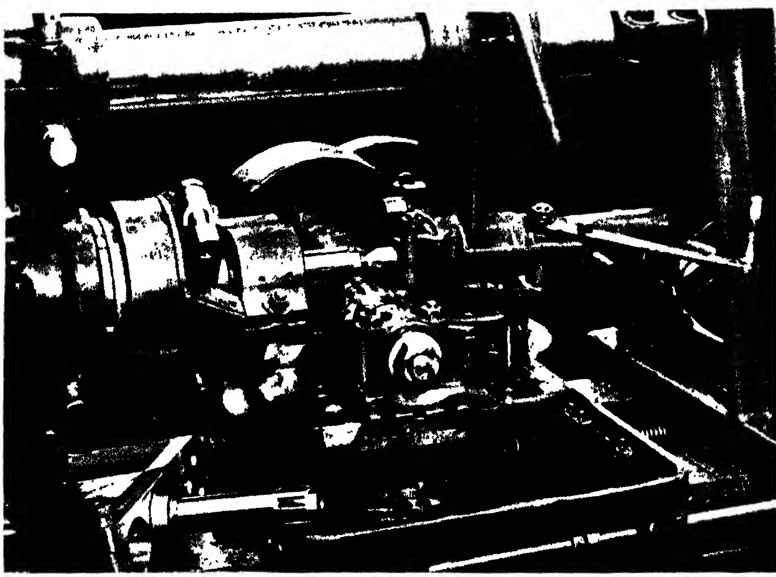

Fig. 21. Hobbing Square Splines on the Rear Section of an Airplane-engine

upper lap being raised for reloading. The work is driven at a speed of 180 R.P.M., and at the same time is given an axial stroking motion at the rate of 90 reciprocations per minute. Lapping is performed in one direction for 20 seconds, after which the rotation of the work is automatically reversed and lapping is continued for another 20 seconds. The machine stops automatically at the end of this time. A cam controls the time cycle, and if desired, the lapping time can be extended to two minutes in each direction before the machine stops.

Oil-pumps build up a pressure of 100 pounds, exerting a load on the laps that tends to prevent their rotation, but this pressure can be varied to suit conditions. As a general rule, the cast-iron laps have a life of from 8000 to 10,000 gears.

Another type of gear lapping machine is shown in Fig. 19. In this operation, an internal cast-iron lap is driven by the spur gear to be lapped and, at the same time, the gear is reciprocated about 1/4 inch, so as to distribute the abrasive compound adequately over the teeth of the gear and the lap. The practice is to run each gear in the forward direction for about two minutes and then in the reverse direction the same length of time. The operating speed is approximately 125 surface feet a minute.

Forming Internal Splines with Gear Shaper of Horizontal Type.—Internal splines are being cut in the end of a crankshaft for an airplane engine in the operation illustrated in Fig. 20, which is performed on a horizontal gear shaper. This machine was specifically designed for cutting spur or helical teeth on gears and clutches that are integral with long shafts. The front end of the work is held in an adapter mounted in a spindle which has a hole 18 inches in diameter in it. The outer end of the work, which extends toward the left, is supported by a bracket on a slide that is adjustable along the machine base for positioning the work in relation to the cutter. The cutter-spindle is contained in a head which is adjustable along the base in a direction at right angles to the work-slide; this adjustment controls the diameter setting of the cutter with relation to the work.

Forming Splines by Hobbing. — In Fig. 21 is shown a hobbing machine producing square splines on the rear section of an airplane-engine crankshaft. The cutter is made with four series or rings of teeth, so that long life can be obtained by adjusting the cutter horizontally as any series of teeth becomes worn beyond the desired limits. Six splines, 0.372 inch wide, are cut within plus or minus 0.0005 inch around the crankshaft.

Machine Tools Designed for a Single Purpose or Operation

Some machine tools are designed for operating on a given part only. These special or "single-purpose" machine tools are only used where large numbers of duplicate parts are required. In many plants, one or more single-purpose machines may be used continuously owing to the large production. Such machines are often found in automotive plants and they are an important factor in reducing manufacturing costs. The design of a single-purpose machine tool naturally depends upon the job it is to perform. In other words, the machine is designed around the particular work it is intended for. There are also machine tools that are similar to the single-purpose type in so far as operating efficiency is concerned, which, with more or less modification or adjustment, can be adapted to a limited range of work. These special or semi-special types are used for quite a variety of manufacturing operations in the larger plants. This section includes some interesting examples of work done on special machines.

These special machines should be built only when there are definite indications that they will pay for themselves before they have to be discarded, possibly because of radical changes in the design of the product. Within recent years many special machines have been constructed from standard bases, tables, hydraulic heads, etc., that can be rearranged into other machines when changes in product design make them unsuitable for their original purpose.

Machine for Drilling and Tapping Cylinder Blocks.—In a large plant for manufacturing truck engines there is a considerable number of special machines designed to obtain

maximum production by performing multiple operations. One of the outstanding machines in this class is for drilling and tapping a large number of holes in cylinder blocks. In this machine, shown in Fig. 1, each cylinder block is automatically located and clamped in three stations, to which it is automatically indexed. In each indexed position, multiple-spindle heads are advanced for drilling or tapping. If any one clamp or spindle should fail to operate in the proper sequence, the entire machine will stop automatically.

Turning Hub Ends of Airplane Propellers.— A machine of special design for turning the hub end of propeller blades is shown in Fig. 2. The photograph was taken from the

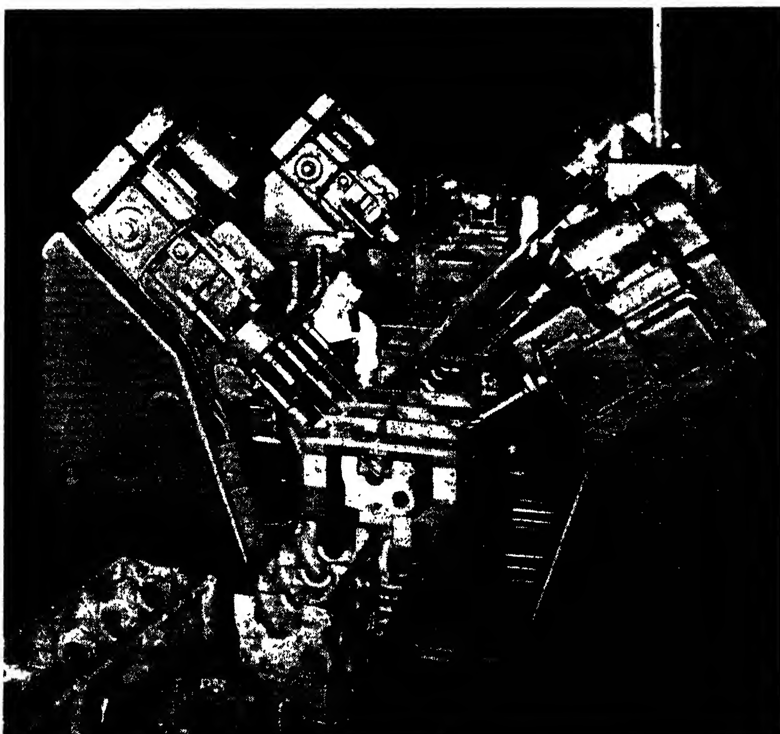

Fig. 1. Special Machine which Automatically Indexes Cylinder Blocks and Clamps Them for Drilling and Tapping

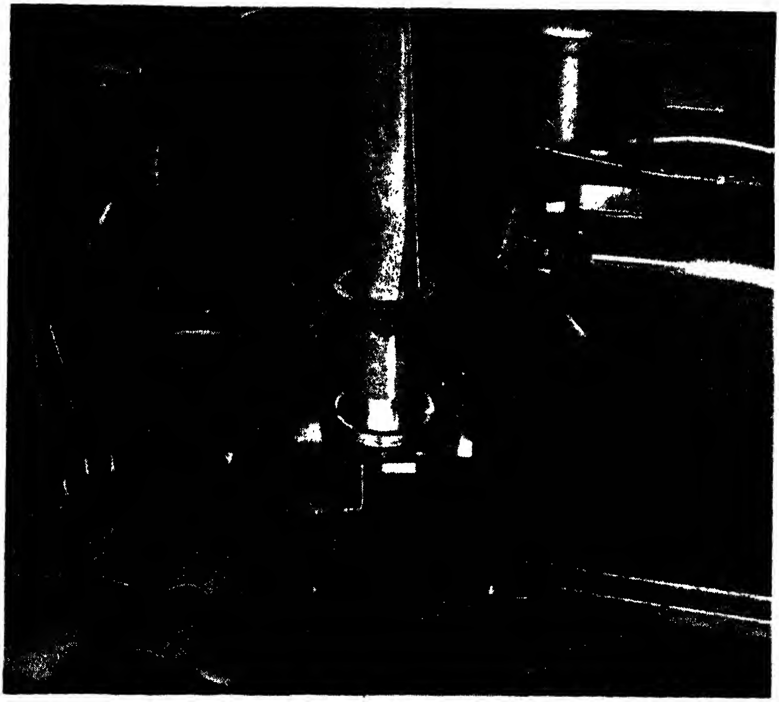

Fig. 2. Special Machine Designed with Three Tool-heads for Taking Turning and Facing Cuts on Propeller-blade Shanks

back of the machine, so as to show the three tool-slides, which are hydraulically actuated to and from the work. The tool-head seen at the left moves forward to the work and then feeds downward under a cam control to turn the taper. The slide then stops and the tool-arbor swivels on its axis for turning the large fillet that joins the shank portion to the flange. At the same time, the tool-slide at the right goes through a combined angular and vertical movement for turning two straight surfaces on the flange and beveling two edges. While these slides are in action, the slide seen in the foreground moves forward at an angle for facing the bottom of the flange.

Multiple-head Machine for Machining Spark Plug Holes in Cylinder Heads.—Machining the two spark-plug holes in the aluminum cylinder heads of airplane engines, is done

by using the multiple-head machine illustrated in Fig. 3. There are six working stations around this machine, one of which is used for loading purposes. In each of the remaining stations there are two tool-heads, one of which is positioned vertically, and the other in an angular plane extending toward the outside of the machine. The cylinder heads are loaded into fixtures mounted on a circular table which is indexed around the machine column to carry the

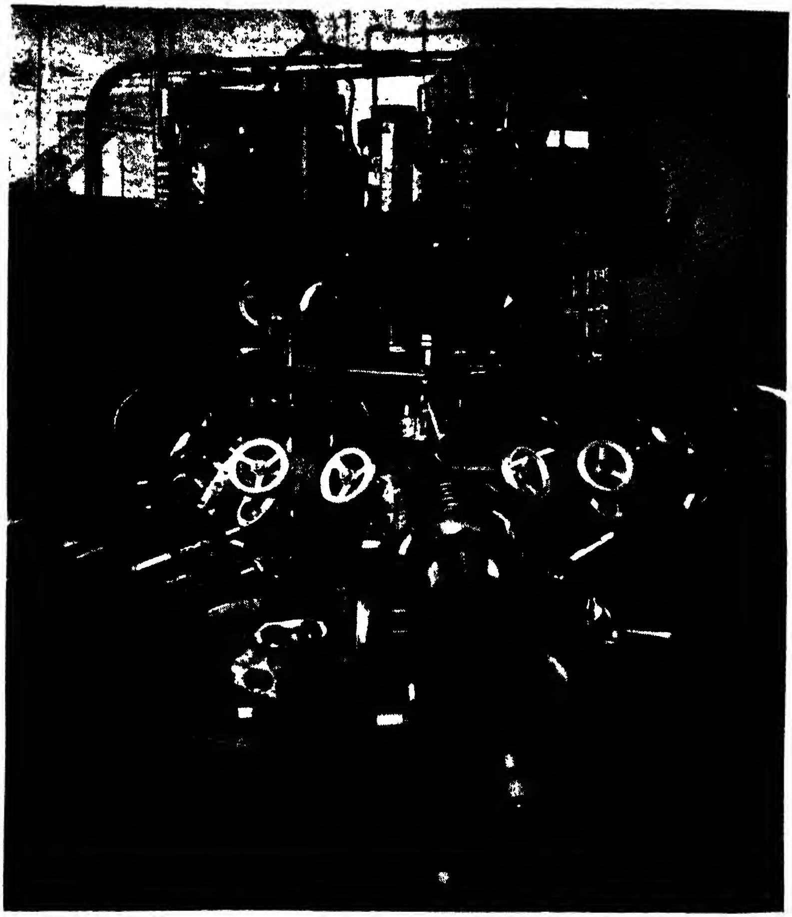

Fig. 3. Multiple-head Machine that Simultaneously Performs Various Operations on the Two Spark-plug Holes in Aluminum Cylinder Heads

Fig. 4. Automatic Buffing Machine for Pistons

work to each pair of tool-heads. Identical operations are performed by both tool-heads of a pair on opposite spark-plug holes. The operations in sequence consist of spot-facing, drilling, reaming, countersinking, and tapping. The tool-heads are actuated hydraulically to and from the work, while the indexing is accomplished automatically by mechanical means.

Polishing Aluminum Pistons. — Polishing aluminum pistons is done by the machine shown in Fig. 4. This machine finish-buffs the sides, and the flat and bevel on the top in 15 seconds, as against 10 minutes with a hand operation. Each of the six buffing wheels is driven by V-belts from its own motor, and is equipped with a pneumatically oper-

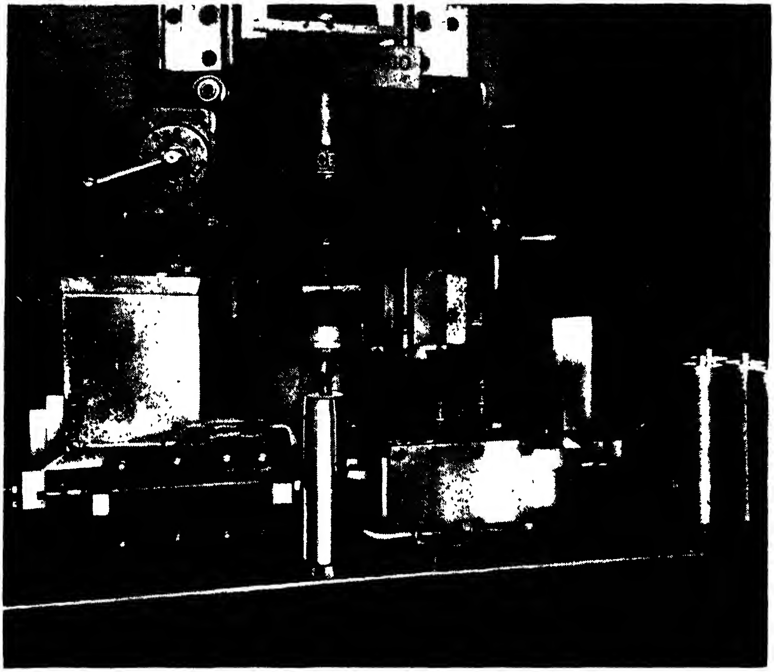

Fig. 5. The First of Two Precision Turning Operations Performed on Artillery Shells with Tungsten-carbide Tools

ated device which applies buffing compound automatically at each indexing of the table.

The pistons are located, two at a time, on chucks seen unloaded at the front of the machine, and the table indexes automatically. The chucks rotate during the buffing operation, but are stationary during indexing. Rotation also stops as the chucks come into the loading position. The table accommodates twelve pistons, but only six are actually buffed at one time. The guards that normally cover each wheel were removed when the photograph was taken, so that the wheels could be more clearly seen.

Turning Shell Forgings.— Shell forgings of the 3-inch and 75-millimeter sizes are turned in two operations on machines of the type shown in Fig. 5, after they have been rough-machined in a lathe. The shell is supported between

a large center at the bottom and a conventional center at the top. The turning cuts are taken simultaneously by tungsten-carbide tools mounted on two carriages, the one at the right of the work being fed from the top of the forging to the middle, and the one at the left from the bottom of the forging to the middle. During these feeding movements, the tool rams are fed in and out horizontally to suit the contour of the shell. These movements are produced by the engagement of a tongue near the outer end of each ram with cam bars attached to the machine frame. When the tools reach the positions shown, the carriages automatically stop feeding and return to their starting positions. They are operated hydraulically.

Cutting Copper Rifling Band Grooves in Shells.—Machines of the design illustrated in Fig. 6 are used in shell manufacture for cutting a dovetail groove to receive a copper rifling band at the point where the straight external surface of the shell approaches the taper of the base end. In addition to the groove being under-cut at an angle along each side to form the dovetail, wavy annular ridges must be machined completely around the bottom of the groove to prevent the copper band from turning on the shell when it is discharged from a gun.

For this grooving operation, the straight portion of the shell is gripped by the jaws of an air-operated chuck. The cutting tools are mounted in three slides that are positioned radially around a head of "automotive brake" design which has a circular slide that is operated hydraulically to feed the three tool-slides radially toward the work.

On the front side of the tool-head (the back is seen in the illustration) is a slide equipped with a tool that cuts the groove to approximately its full width at the top as it feeds into the work. The cutting edge of this tool is ground with two V-grooves which allow stock to remain at the bottom of the groove to form the wavy annular ridges. The "waves" are produced by sliding this tool-block sidewise three times during each revolution of the work. This oscillation is accomplished by a face-cam on the headstock spindle against which a roller attached to the grooving

tool-slide rides under spring pressure. The sidewise oscillation imparted to the grooving tool is about 3/16 inch.

At the back of the tool-head is a slide, provided with a tool that is fed toward the work at an angle of 20 degrees to under-cut the groove on one side. A similar tool above the work descends to cut the opposite side of the groove to the same angle, the two tools thus forming the dovetail. When the shell is taken from this machine, the operator applies a chisel and hammer to dent the wavy annular ridges at three points around the shell so as to provide vents for the escape of air from between the ridges when the copper rifling band is assembled.

Assembly of the copper rifling band is then accomplished

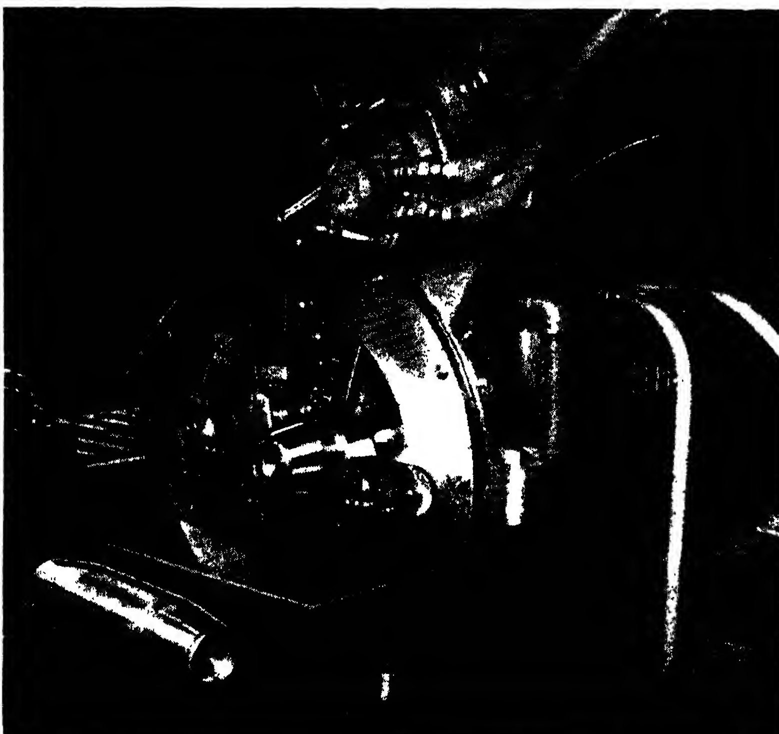

Fig. 6. Ingenious Tooling Provided on a Special Machine Employed for Cutting the Dovetail Rifling-band Groove, with Its Wavy Annular Ridges, around the Shells

in a tire-setter machine. For this operation, the copper band is slipped over the shell and into the groove, and the shell is placed upright in a bushing in the center of the machine. Six sliding jaws on the machine are then closed in on the shell, completely covering the copper band. The jaws are operated by individual hydraulic cylinders at a pressure of 1000 pounds per square inch and compress the band approximately 3/8 inch on the diameter. The band is about 1/16 inch larger in inside diameter than the straight portion of the shell prior to this squeezing process.

Turning Copper Rifling Band to Required Contour.—The copper band is next turned to the proper contour in the lathe illustrated in Fig. 7, which is equipped with a special

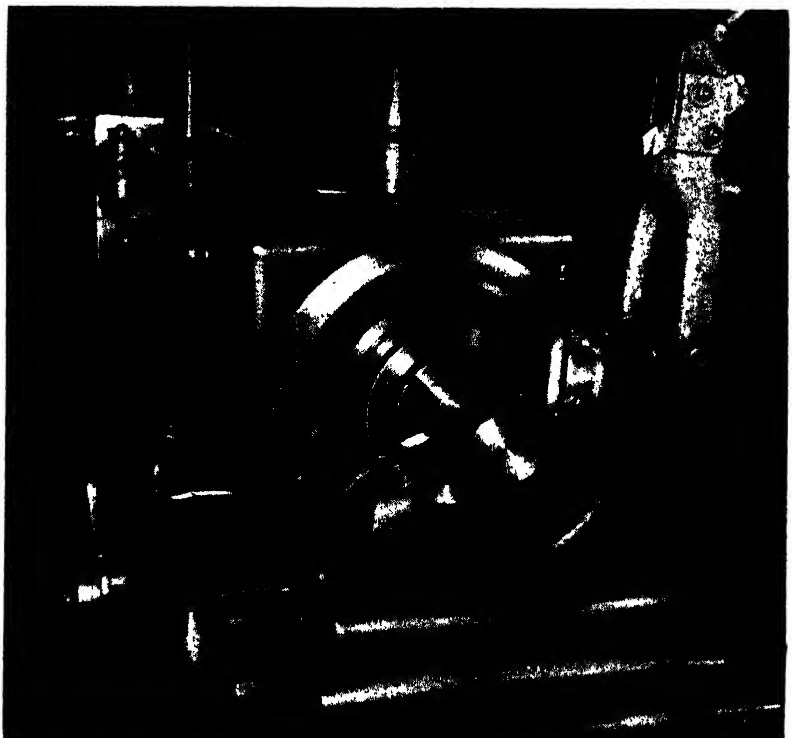

Fig. 7. Special Tooling Provided for Turning the Copper Rifling Band to an Irregular Contour and Cutting Fine Grooves around the Band

cross-slide that carries four tools. The operator moves the cross-slide in and out by hand to feed the tools to the work successively. First the cross-slide is fed forward into the position illustrated to bring a vertically held forming tool against the work for rough-turning the copper band. Then the operator moves the cross-slide into a central position and swings down an overhead arm that is equipped with two cutters for turning narrow flat surfaces on both edges of the copper band to a width of 0.020 inch. These tools are then again raised into the position shown, and the cross-slide is fed toward the rear to bring into action a form cutter at the front of the cross-slide which finish-turns an irregular surface around the copper band and

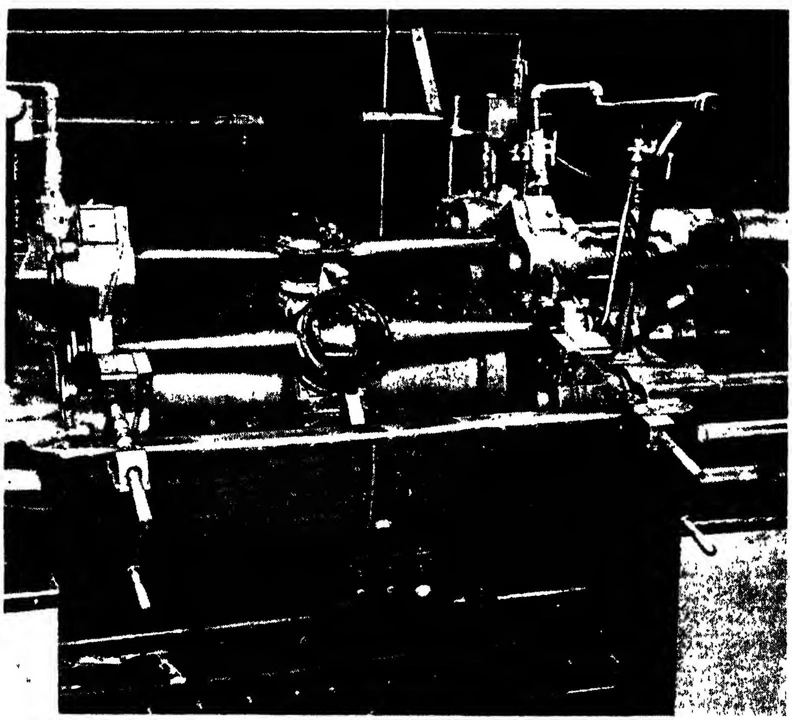

Fig. 8. A Hydraulically Operated Double-end Machine which Performs Several Machining Operations on the Two Ends of Rear-axle Housings

cuts five fine annular grooves around one of the taper sides on the band.

Machining Ends of Rear-axle Housings.—Both ends of truck rear-axle housings are machined simultaneously in the machine illustrated in Fig. 8, which is equipped with a seven-station trunnion fixture. The rear-axle housings are centrally located in the fixture from the banjo face, equalizing fingers registering in the bore of the banjo. The ends of the housings are placed in jaws of an equalizing design, which are locked by means of two rollers on a slide that is advanced on each end of the housing by turning a screw. The screw is turned by socket wrenches attached to the crank-handles shown.

From the loading position, the work is indexed forward and around the bottom of the machine. With each indexing, a hydraulically operated tool-head on each end of the machine advances tools to the work. Pilot-bars on the tool-heads engage bushings in the rotary fixture to insure accurate alignment of the work with the tools and to lock the fixture securely for each operation. The tool-heads recede rapidly at the end of their forward movements to allow the fixture to index again and bring another rear-axle housing into the correct position relative to the tools.

In the second station of this machine, the bearing and retainer bores are rough-bored and chamfered on both ends. In the third station, the bearing bores are semi finish-bored, the retainer bores are finish-bored, and the flanges are turned and chamfered. Both sides of the two flanges are rough-faced in the fourth station by tools that are fed inward radially along the sides of the flanges. Both outer faces of the flanges are then semi finish-faced in similar manner in the fifth station.

The bearing bores are finish-reamed in the sixth station, and in the seventh station, which is seen at the top of the machine, holes are drilled and reamed in the flanges by combination tools.

Drilling, Milling, and Threading Rear-axle Housings.—In Fig. 9 is shown a large machine of special construction, designed for performing a number of operations on rear-

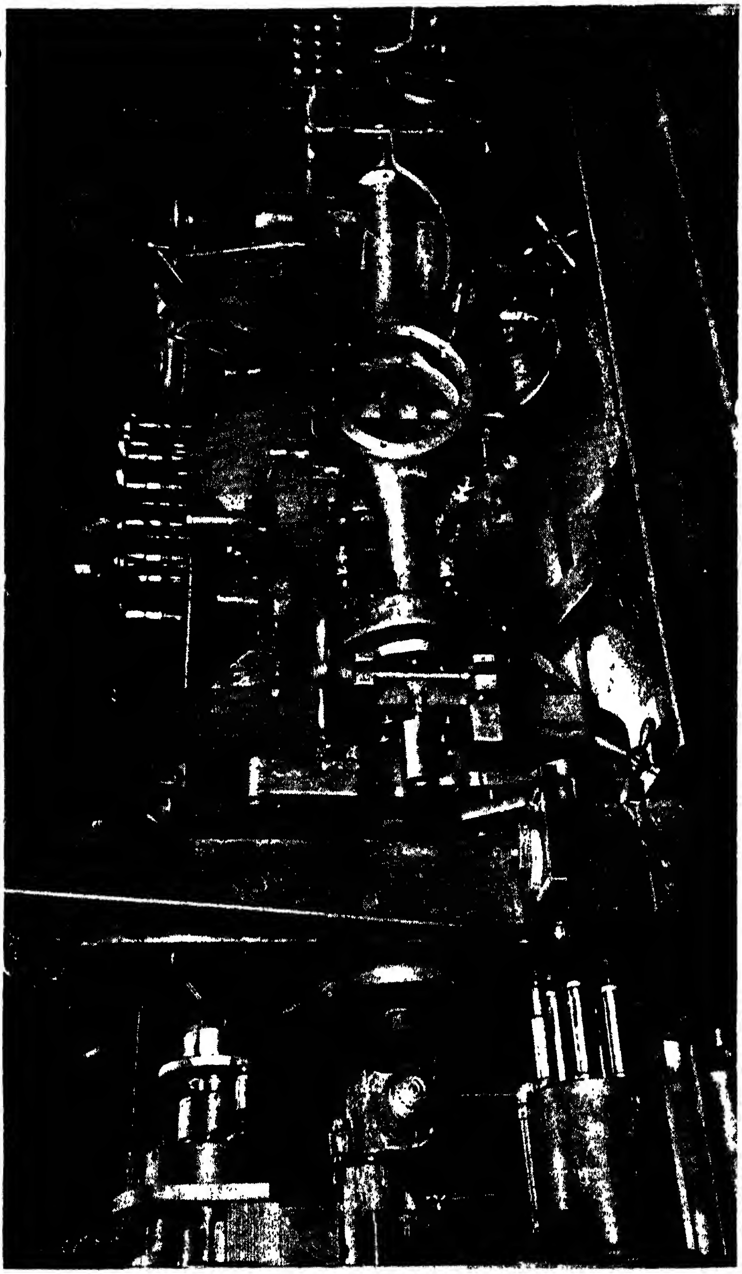

Fig. 9. Indexing Type of Machine that Drills and Taps Holes in Rear-axle Housings, Threads Axle Ends, and Cuts a Keyway across Threaded Surfaces

axle housings for 1 1/2- and 2-ton trucks. From the loading position at the front of the machine, the work is indexed downward 90 degrees to a bottom station, where a multiple-spindle head feeds in from the left to drill all the holes in one of the wheel flanges. The housing is then indexed to a third position at the back of the machine, where a horizontal head slides in at right angles to the housing for drilling fourteen holes around one of the banjo faces. At the same time, a head at the left-hand side of the machine advances a small circular milling cutter for cutting a keyway along the end of the cylindrical surface on the axle. Finally, in the fourth station, at the top of the machine, the holes drilled in the banjo in the third station are tapped by the spindles of a multiple head mounted vertically on the upper cross-bracket of the machine. At the same time, threads are cut on the end of the axle by a die-head equipped with circular chasers, which is fed in from the left.

When one end of the housing and one banjo face have been machined as described, the axle housing is turned end for end while in the loading station of the fixture for a second passage around the machine, during which the opposite axle and banjo face are machined. From the illustration it will be seen that the housing is adequately supported at both axles, and accurately located both from the axles and the banjo face opposite the one being machined.

Chamfering Ends of Transmission Sleeves.—A machine developed for simultaneously chamfering the ends of two second-and-third speed sliding sleeves for automobile transmissions is shown in Fig. 10. This operation is performed after the internal helical splines have been broached. The sleeves are placed in V-blocks at the front and back of a fixture located between two hydraulically actuated tool-heads. As loaded, the center of each sleeve is slightly below the center of the corresponding tool-spindles, and one end of the sleeve is located against a vertical shoulder on its respective V-block.

When the tool-heads advance, taper pilots on the tool-spindles enter the splined hole in the work-pieces and raise

them to the center of the tools. At the same time, a finger on each rear tool-head pushes the work-pieces firmly against the locating lugs on the V-blocks. Then, hydraulically actuated jaws on the work-fixture operate crosswise to grip the work-pieces for the chamfering operation, which occurs as the tool-heads advance at a reduced rate of feed. Each tool pilot is provided with a needle-bearing roller, due to the fact that the pilot must stand still in the stationary piece while the tool-spindle revolves. One man tends both this machine and the spline broaching machine, and obtains a production of 180 pieces an hour from both.

Three-station Type of Machine for Airplane Propeller Hubs.—Three successive operations are performed on all three barrels—a total of nine operations—by the three-

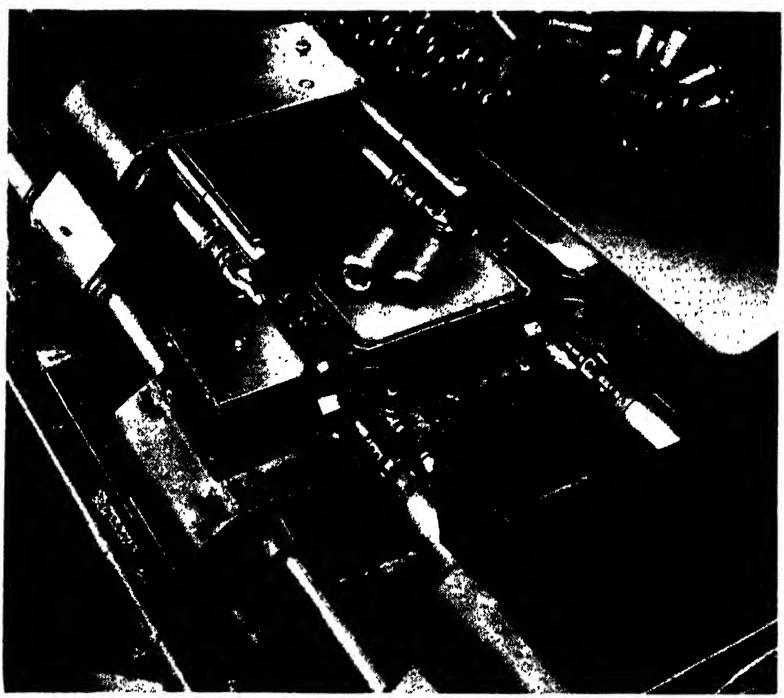

Fig. 10. Machine that Chamfers Both Ends of Two Sliding Transmission Sleeves in Accurate Relation to Splined Bores

spindle machine illustrated in Fig. 11. This machine is equipped with a three-station drum which carries the hubs around a horizontal shaft to the three working stations, one barrel only of all three forgings being operated upon during a single cycle. When each hub returns to the first station, it is indexed through 120 degrees to bring the second barrel toward the tool-spindle for the next cycle. At the end of the second cycle, the hub is again indexed for machining the third barrel. One hub is finished in every three machine cycles. The operation consists of boring the barrels to a diameter of about 7 inches, and forming a contour at the bottom of each barrel. Indexing of the fixture drum is accomplished mechanically, but the individual fixtures are indexed manually. The tool-head of the machine is operated hydraulically.

Station Type of Machine for Preliminary Operations on Connecting-rods.—A machine (see the close-up views, Figs. 12 and 13) performs preliminary operations on automobile connecting-rods. When the rods are placed in this machine, they are integral with their caps, the practice of forging the rods and caps in one piece being followed in this plant in order to obtain the caps at a negligible forging cost. When the rods leave the machine, the crankpin ends have been core-drilled and milled on the bolt bosses, the wrist-pin ends drilled and reamed, and the caps sawn from the rods. Three stations are provided on this machine, one for loading and two working stations.

Four rods are held by each of the three indexing fixtures. After the forgings have been loaded into a fixture, they are clamped by power-driven socket wrenches actuated by a drive at the front of the machine. When the wrenches are driven in the forward direction, equalizing clamps are drawn tightly down on each connecting-rod to grip the crankpin end at two points and also to grip both sides of the wrist-pin boss. The clamps are operated by vertical screws in the fixture, which are driven from the wrench-shafts through worm-wheels.

The fixtures are indexed from the loading station around the column of the machine toward the left. The first work-

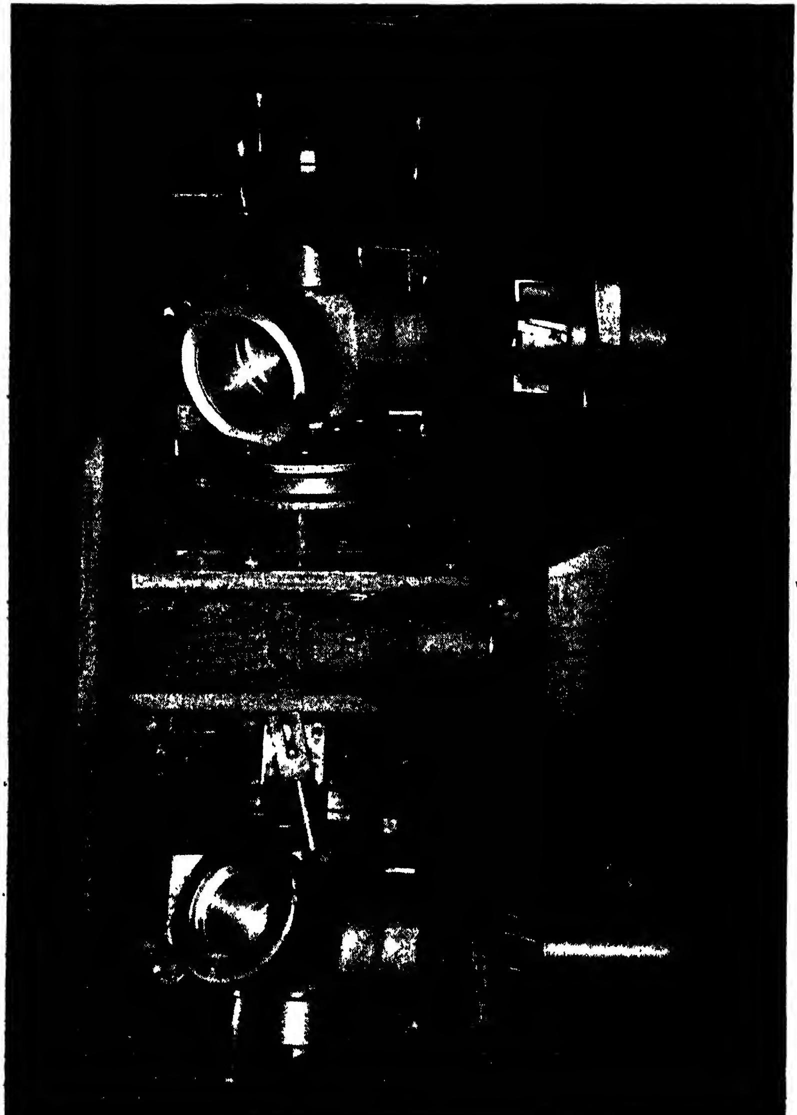

Fig. 11. Drum Fixture and Tooling Used in Performing Three Operations on Three Hub Barrels with Nine Indexings of the Fixture

ing station, which is shown in Fig. 12, is provided with a vertically operated tool-head, equipped with four inserted-blade core drills for rough-machining the crankpin bearings of the rods, four conventional drills for drilling the wrist-pin ends, and five horizontal arbors on each of which cutters are mounted for straddle-milling the top, bottom, and sides of the bolt lugs on the crankpin ends. From the illustration, it will be seen that the crankpin ends of the connecting-rods are supported on hollow blocks that permit the core drills to pass through the work. Generous openings provide for ready disposal of the chips. Heavy pilot-bars on the tool-head engage bushed holes in the ends of the fixture to insure accurate location of the tools relative to the work-pieces. The production on this operation is 200 connecting-rods an hour.

Fig. 12. Tooling for Drilling the Crankpin and Wrist-pin Holes and Straddle-milling the Crankpin End of Connecting-rods

In the next station of the machine, which is shown in Fig. 13, five circular saws come down between the four connecting-rod forgings and cut the caps from the rods. At the same time, four reamers at the back of the tool-head machine the wrist-pin bores of the rods. The saws are 6 inches in diameter and 0.135 inch thick. The cut-off caps, as well as the rods, are held firmly by the clamps until the fixtures are indexed into the loading position. The two tool-heads of this machine, as well as the wrench unit, are equipped with independent motor drives. Both the tool-heads and the table are operated hydraulically.

Machining Bearing Caps.—An unusual machine employed for operations on the bearing caps is illustrated in Figs. 14 and 15. The castings are loaded in the starting end of this machine between guide bars, as seen in Fig. 14,

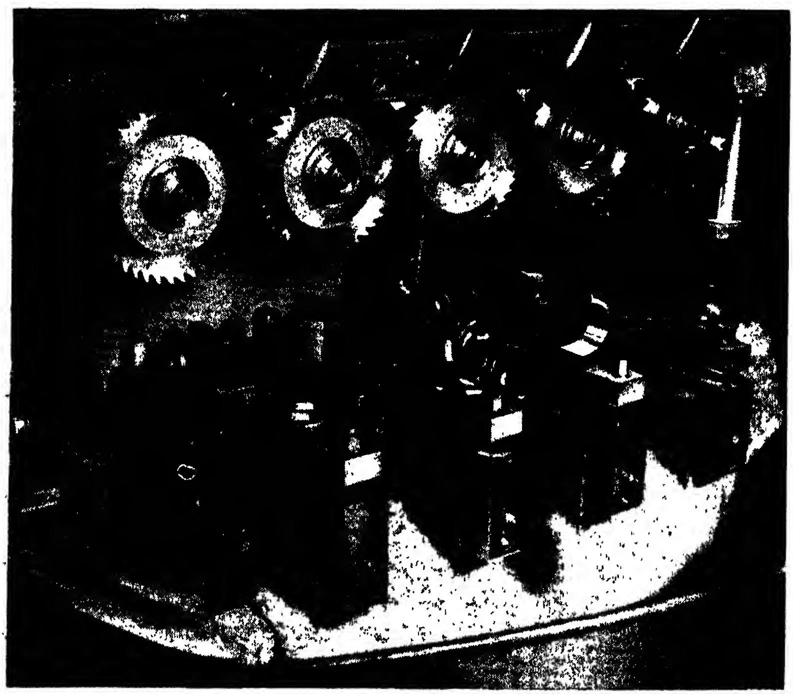

Fig. 13. Circular Saws which Cut the Caps from the Connecting-rods while the Wrist-pin Ends are being Reamed

and are automatically carried to the various working stations of the machine by an intermittently reciprocated bar that projects in front of the guide bars. The castings are accurately located in each working station by an overhead V-block plunger that is lowered on one bolt boss. The shuttle bar is air-operated, and is cushioned by a hydraulic cylinder.

In the first station, a battery of drills mounted in a head on the right-hand side of the machine drills one-half the bolt holes in the casting; this machine is completely tooled to handle castings for either six- or eight-cylinder engines. When the castings are indexed to the next station, the remaining holes are drilled by a second battery of drills on the right-hand head, and at the same time a head at the

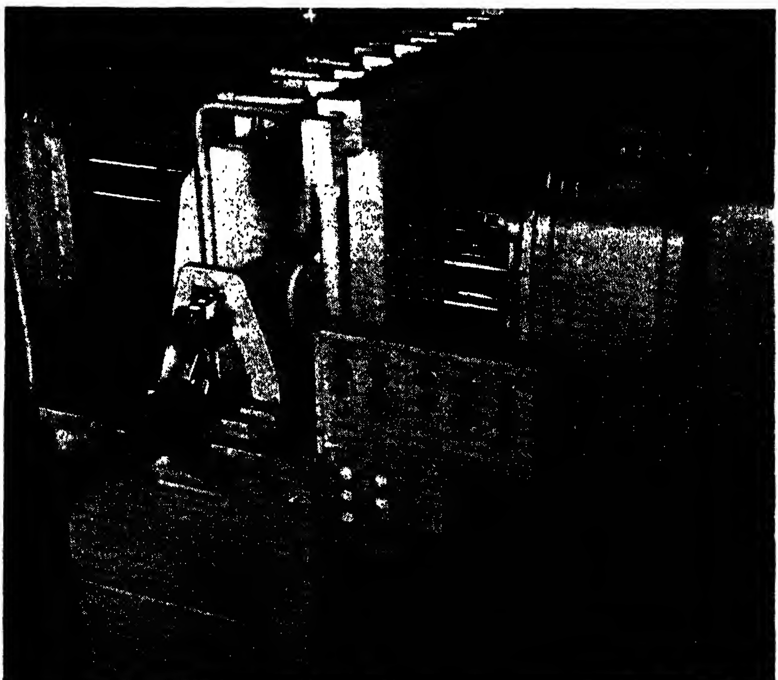

Fig. 14. Starting End of a Machine which Performs Drilling, Spot-facing, Reaming, Tapping, and Milling Operations on Bearing Caps

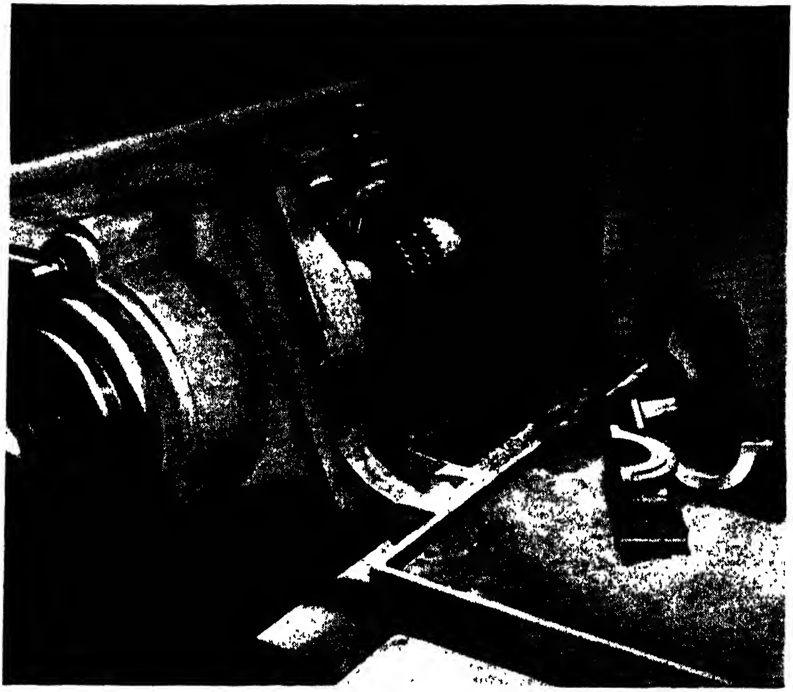

Fig. 15. Finishing End of the Machine Shown in Fig. 14 from which the Individual Caps are Discharged

left is advanced for spot-facing the tops of the bosses that were drilled in the first station. In the third station, tools mounted on the right-hand head ream two holes in the portion of the casting that is to form the rear bearing cap, while tools on the left-hand head spot-face the remaining bosses of the casting.

Several idle stations then occur along the guide bars to provide space for servicing the machine, after which the castings reach a station where cutters on a horizontal arbor of another tool-head are advanced for milling the lock-slots. The cutters are permanently mounted on this arbor, the arbors being changed to suit castings for six- and eight-cylinder engines. Four slots are milled in the castings for six-cylinder engines, and five slots in the castings for eight-cylinder engines.

After passing through several additional idle stations, the castings reach a station opposite the milling head seen in Fig. 15, which advances narrow slitting saws for cutting the caps apart. The castings are clamped in this station by horizontal plungers that are applied at several points, so that the separate caps will be held firmly until the slitting operation has been completed. The arbor of this slitting head is also changed to suit castings for six- and eight-cylinder engines. While the slots are being milled another head on the opposite side of the machine taps a hole in one cap of each group.

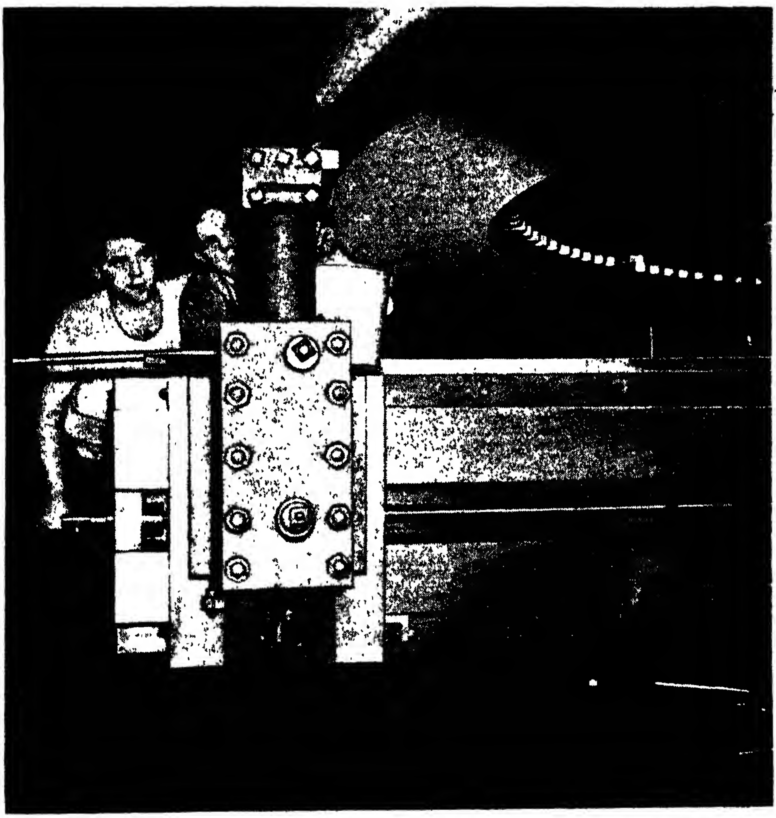

Fig. 16. Special Machine Devised for Taking Turning, Facing and Boring Cuts on Circular Work at Radii up to 20 Feet

At the end of the slitting operation, the cut-off bearing caps are discharged from the guide bars of the machine on a tray, as seen in Fig. 15. This tray is tilted upward each time the slitting head advances for an operation, so as to provide room for the arbor housing. Similarly, the section of the conveyor track or guide bars is tilted upward each time that the slotting head in the previous station feeds forward. All heads of the machine are hydraulically actuated. When the tray is tilted upward, the bearing caps cut off during the preceding movement of the slitting head slide off the tray and into a tote box. The various clamps on this machine are tightened on the work by weights, and are released through an air-operated camshaft that extends the length of the machine. The machine is approximately 19 feet long, and produces 80 sets of bearing caps an hour.

Turning, Facing and Boring Large Circular Parts.—Equipment especially designed for machining large roller tracks is shown in Fig. 16. This machine consists essentially of a revolving table, which is located under the work and carries a cross-rail extending radially outward as shown. On the cross-rail there is a tool-slide equipped with an adjustable vertical post that carries a block for cutters at its upper end. By rotating the table about the center of the work, a tool can be carried completely around the work for taking turning, boring, and facing cuts. Surfaces up to 40 feet in diameter can be machined.

Drilling Three Large Holes Simultaneously.—The operation shown in Fig. 17 consists in drilling simultaneously two 5-inch holes and one 7 1/4-inch hole through solid gun trunnion forgings 10 inches thick. One of the undrilled forgings is seen lying on the left side of the table of the drilling machine. A finished trunnion is seen on the right-hand side of the table. These forgings are of S A E 4140 steel. The holes are drilled completely through the forgings in thirty-five minutes. When the forging is placed in the machine, it weighs 374 pounds and after it has been drilled and bored, only 94 pounds, approximately 75 per cent of the material having been cut away. The walls are reduced

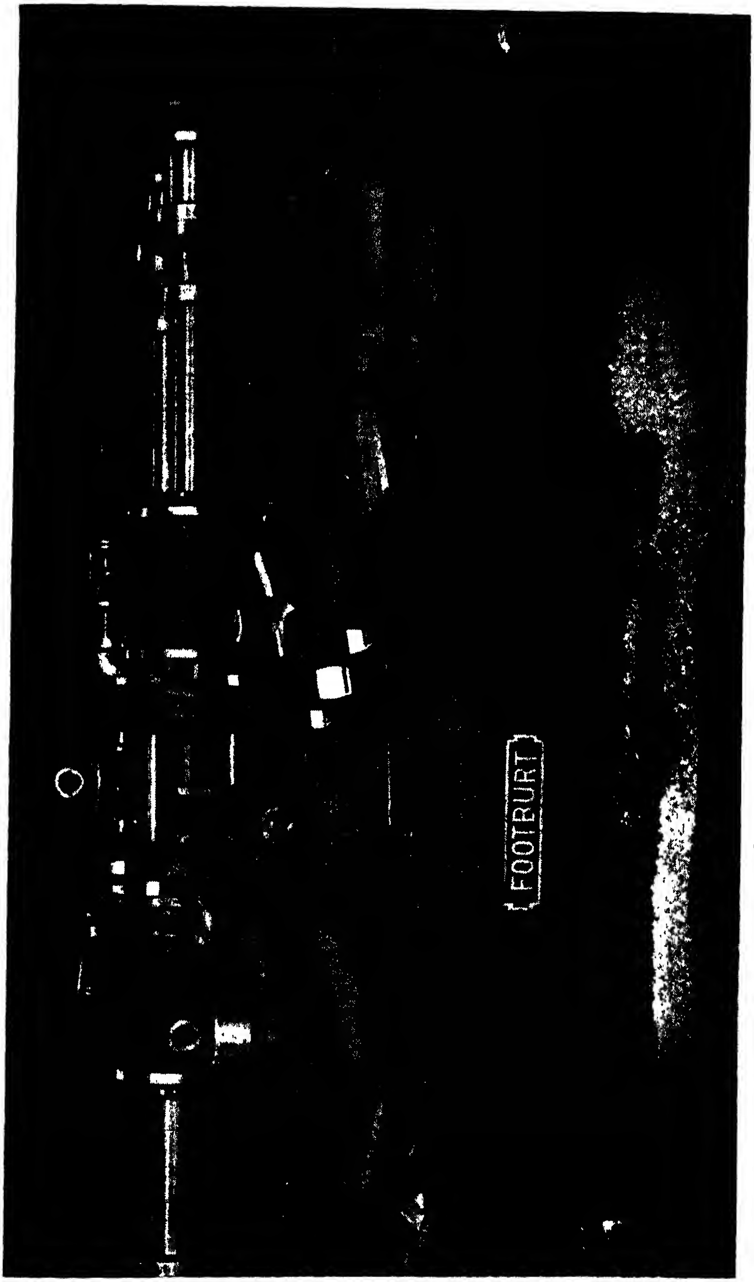

Fig. 17. Drilling Three Large Holes Through Molybdenum Steel Forging

to thicknesses of only 1/4 and 5/16 inch. The machine is provided with hydraulically actuated tool-heads which advance together. Cutter blades of a double-edge type such as seen on top of the drilled part, are used in rough-drilling the forgings. When the rough-drilling has been completed, the double-edged blades are removed from the tool spindles and boring heads with two cutters each are substituted for taking finishing cuts. Approximately 1/16 inch

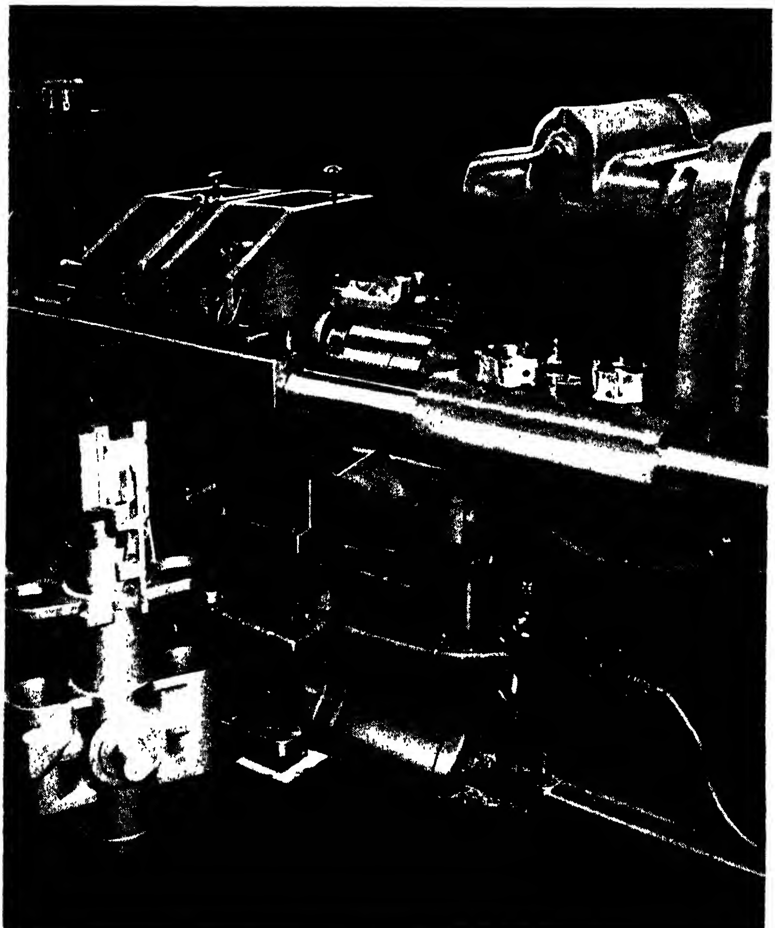

Fig. 18. Machine for Finish-boring and Reaming Gun Cradles

of stock is removed in finishing. The large central bore of this trunnion forging receives a 75 millimeter gun barrel while the two smaller bores on either side are for the recoil cylinders.

Boring and Reaming Operation on Double-end Machine.—The trunnion bores of 75-millimeter gun cradles are remachined after a number of other parts have been welded to the trunnion so as to obtain a gun cradle of the rather complicated construction seen in Fig. 18, in front of a double-end boring machine. Each of the hydraulically operated tool-heads on this machine has three spindles. One head finishes the previously machined bores of the trunnion portion of the assembly, while the spindles of the opposite head finish the holes that are opposite to and in line with the recoil cylinders and with the gun bore.

After the finish boring cuts are taken, the boring heads are removed and reamers are substituted to obtain an accuracy within plus 0.002 inch, minus nothing for the gun bore and within a tolerance of 0.005 inch for the recoil cylinder bores. Close center-to-center distances between all bores are insured by the provision of heavy bars on opposite sides of the machine for guiding the tool-heads in their movements.

Miscellaneous Applications of Standard and Special Tools

The manufacture of machines and other mechanical devices has reached such a high state of development that a great many types of machine tools and other equipment are utilized, and the variety of operations performed is practically endless. Consequently, it is not feasible to include in a single volume all possible applications of every design of standard or special machine. However, in order to broaden the scope of this treatise as far as practical within the limited space, miscellaneous applications are featured in this section. Some of the machines illustrated are standard types adapted to unusual jobs and others are special designs. While manufacturing operations which exactly duplicate those shown may not be encountered, especially in plants making entirely different products, nevertheless the miscellaneous machines and devices to be described embody a variety of useful mechanical principles. These basic ideas may be applicable in different lines of manufacture.

Reaming 600,000 Babbitt Bearings between Grinds.— The final operation on the babbitt bearing in the crankpin end of connecting-rods for a well-known automobile consists of sizing and finishing with a single-blade angular reamer. This operation brings the bearings to size within a tolerance of 0.0003 inch, the maximum and minimum dimensional limits for the diameter being 2.0000 and 2.0003 inches. In addition to accuracy, an unusually high finish is obtained, the reamer blade being tipped with tungsten carbide. Another important advantage derived from the use of tungsten carbide is that 600,000 bearings are reamed,

on an average, per sharpening of the blade. When the blade was made of high-speed steel, the production between grinds was only 1000 connecting-rods, and the blade had to be honed after every twenty-five or thirty rods. It is never necessary to hone the tungsten-carbide blade. The blade is 4 inches long, and it has an angle of 20 degrees with the axis.

For this single-blade reaming operation, which follows a conventional reaming operation in which an expansion type of tool is used, the connecting-rod is placed in a fixture with the wrist-pin bearing located over a plug, as illustrated (see Fig. 1). The opposite end of the connecting-rod floats between finished faces of the fixture, while the fixture and work are fed by hand along the reamer. The fixture is guided by a cylindrical bar on each side of

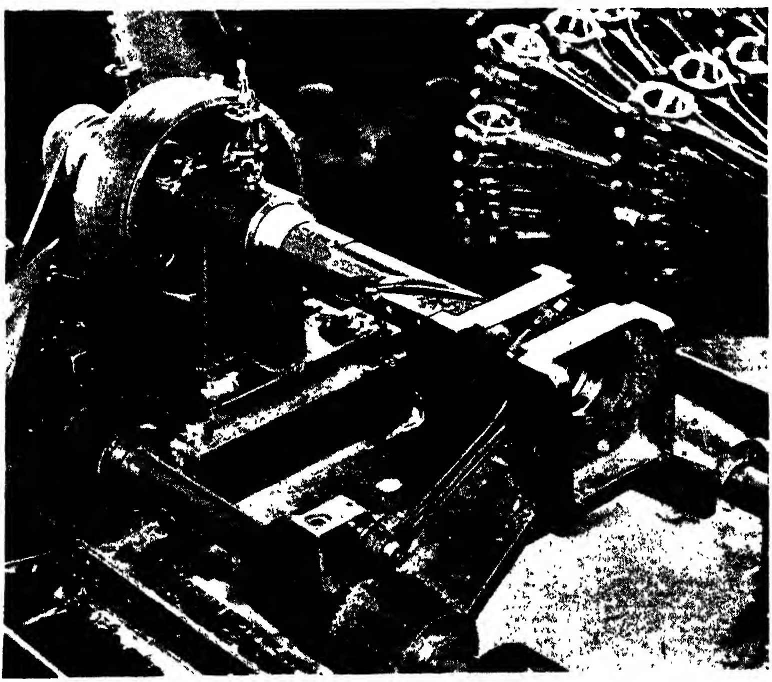

Fig. 1. Reamer with a Single Angular Blade of Tungsten Carbide, which Finishes 600,000 Babbitt Bearings of Connecting-rods between Grinds

the machine. The reamer is run at about 200 revolutions per minute, and soluble oil is used as a coolant. The reamer body is chromium-plated to give long life.

Spline Grinding Operation. — Square splines are being ground on an impeller gear sleeve in the operation shown in Fig. 2. The adjacent sides of two splines are ground simultaneously, the usual practice being to grind around the work three times. In the first grind, the splines are brought to the specified width within about 0.008 inch; in the second grind within 0.0005 inch; and in the third grind within 0.0002 inch. The table is reciprocated hydraulically and the work indexed after each return movement. All together about 0.0015 inch of stock is ground off each side of the splines.

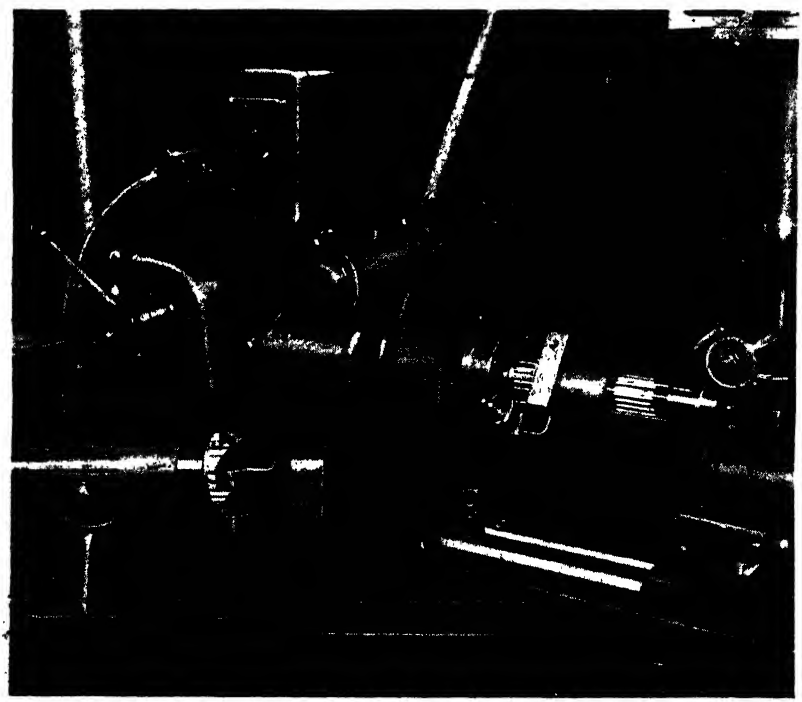

Fig. 2. Grinding Square Splines on the Impeller Gear Sleeve, This Operation being Performed before the Gear Teeth are Ground

Each impeller gear sleeve is placed in a fixture prior to this operation for attaching the driving dog in the correct relation to the previously milled or hobbed splines. The part is mounted between centers on this fixture and placed in the correct radial position by bringing two gaging points into contact with diametrically opposite splines. The driving dog is then attached to the work with an extension of the dog located between studs on an arm of the fixture. When the work is placed in the machine, the set-up is accurate within about 0.001 inch.

Turning Crankpins with Machine of Rotating-tool Type.—The machine illustrated in Fig. 3 is employed for simultaneously turning two crankpins on the crankshafts for large Diesel engines. Crankshafts for these engines are

Fig. 3. Two Crankpins of Each Crankshaft Section are Simultaneously Finish-turned with This Machine by Two Tool-heads Revolving around the Stationary Crankpins

built up from individual crankpins, journals, and crank-arms. The crank-arms are bored and shrunk on the turned pins and journals. Sections of a crankshaft are built up to include one journal and three crankpins prior to the finish-turning of the crankpins, three such sections being later built up into a complete crankshaft; for example, the crankshaft for a six-cylinder engine has eighteen crankpins.

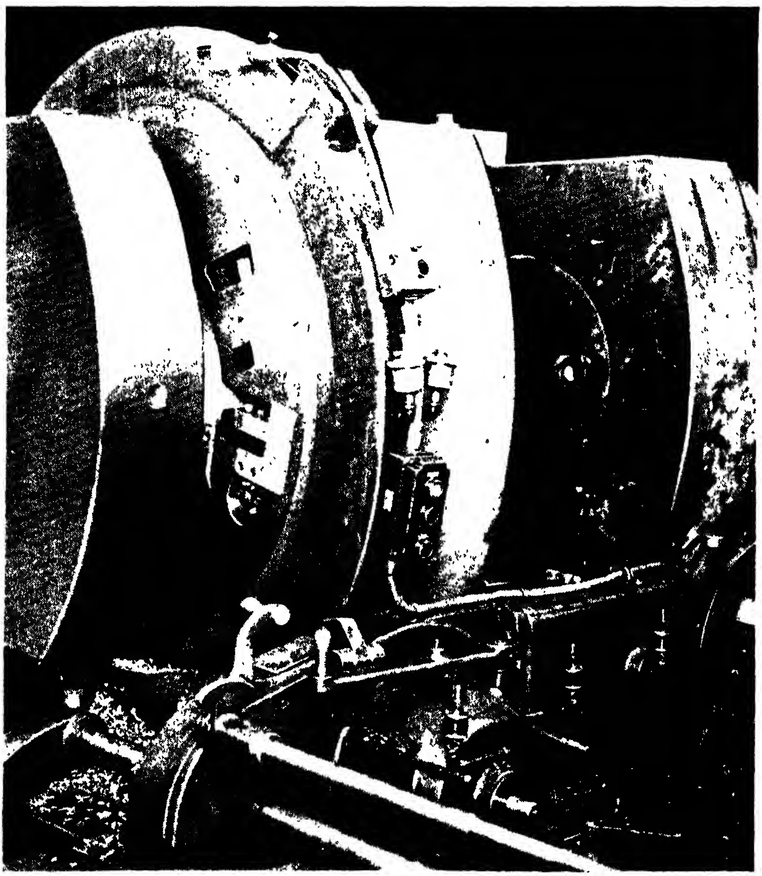

Fig. 4. Close-up View of One of the Tool-heads on the Crankpin Finishing Machine, Showing Split Design which Enables One-half of the Tool-head to be Swung upward for Loading and Unloading the Work

In this crankpin finishing machine, the crankshaft section remains stationary while cuts are taken by tools mounted in heads that revolve around the crankpins. From the close-up view of the tool-head shown in Fig. 4, it will be seen that the head is split through the center and hinged so that it can be swung upward for loading and unloading the crankshaft. The work is supported between centers for the operation. A crankshaft section such as illustrated weighs about 20 tons and is lifted into and out of the machine by means of an overhead crane.

Tools are mounted on both sides of the tool-head to provide for machining the crankpin the full distance between the crank-arm cheeks, part of the surface being machined as the tool-head moves from left to right and the remaining portion as the head moves from right to left. At the end of each complete feeding movement, the tools are fed to depth by the operator's applying a wrench to the special nut seen just below the tool-holder. Three tools can be applied simultaneously on each side of the tool-head, but it is customary to use only one tool on each side. The tool-heads are run at speeds from 25 to 40 feet a minute.

Crankpins are turned to size within plus or minus 0.001 inch, and a similar tolerance is specified for both roundness and parallelism. In the illustration shown, the crankpins are being turned to a nominal diameter of 24 inches. For the final finishing cut, a gooseneck type of tool is used. The crankpins are later hand-lapped.

Planing Ship Propeller. — Constant-pitch propellers are machined on their front or leading side by the large draw-cut shaper illustrated in Fig. 5. The operation illustrated is being performed on a propeller for a destroyer. The propeller is mounted on a circular table which is geared up with the mechanism that feeds the ram, so that with each upward feed movement of the ram the table revolves a proportionate amount toward the path of the tool. This synchronizing mechanism is applied to a standard machine. In planing a propeller, the practice is to take roughing cuts successively on all three blades instead of finishing one blade before starting the next.

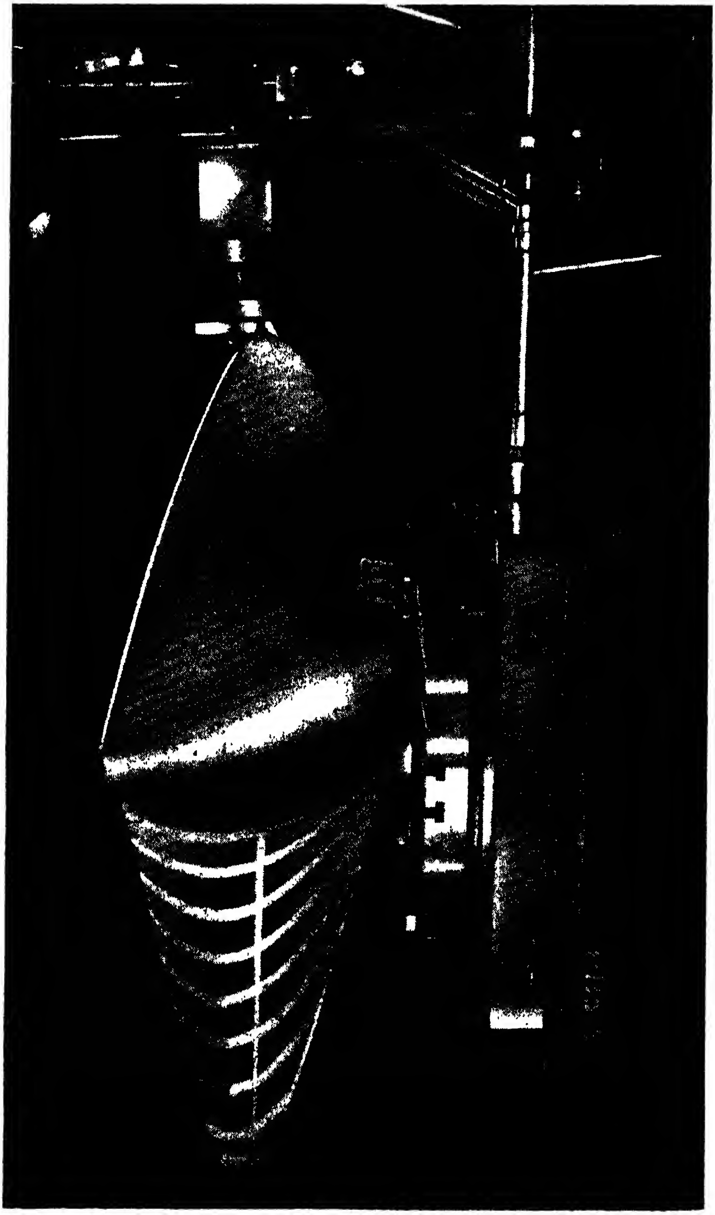

Fig. 5. Planing the Leading Side of a Large Constant-pitch Propeller with a Draw-cut Shaper

Example Showing Application of Nibbling Machine.—Nibbling machines are employed for cutting plates to scribed outlines, as will be seen in Fig. 6, which shows a nibbler in operation. This machine is used on mild steel up to 3/4 inch thick. Large plates are readily manipulated under the nibbling tool, because they are supported on ball transfers which make it easy to shift the plate in whatever direction is required. These devices are assembled at the upper ends of pipes, on a level with two knurled rollers on the machine that support the plate under the nibbling tool, as seen in the illustration. When a plate is fed to the nibbling tool, a small knurled roller attached to

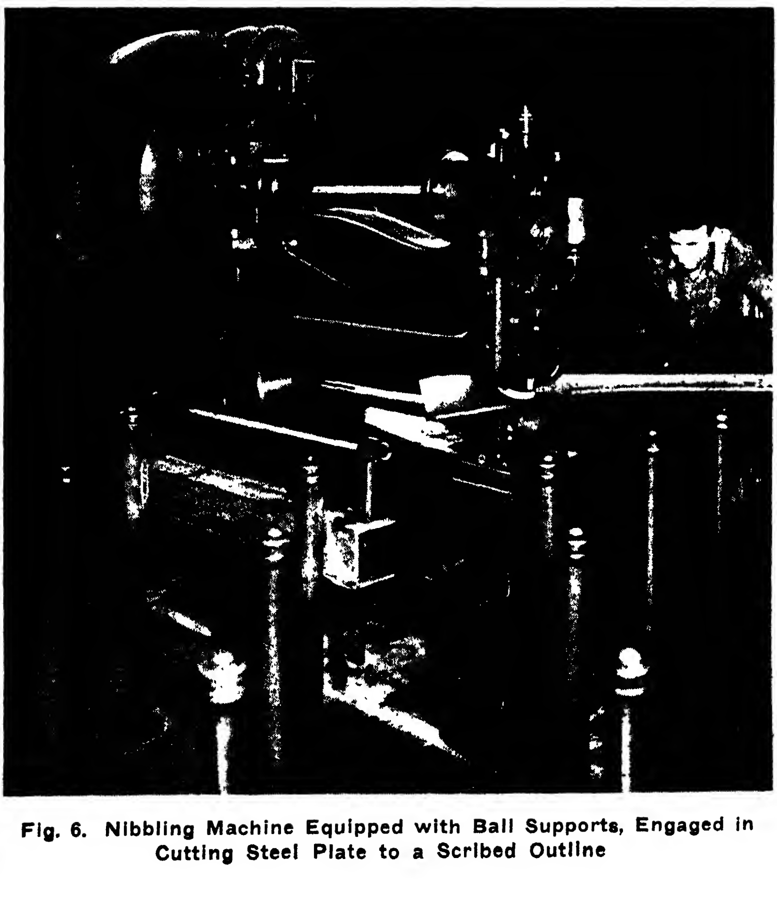

Fig. 6. Nibbling Machine Equipped with Ball Supports, Engaged in Cutting Steel Plate to a Scribed Outline

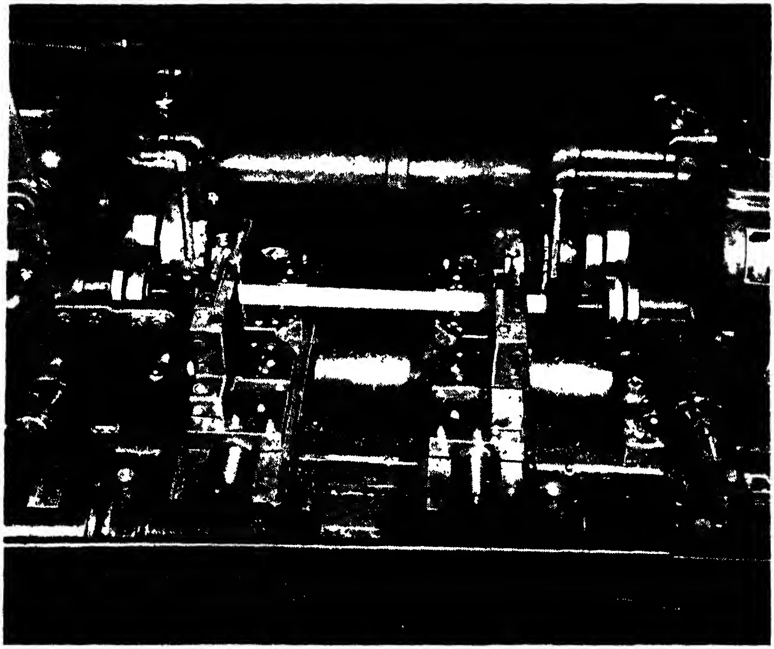

Fig. 7. Milling Rifle Barrel Stock to the Specified Length within 0.010 Inch, and Center-drilling and Countersinking the Barrels in the Same Operation

an arm at the right-hand side of the machine is lowered on the plate in back of the tool to hold it firmly on the bottom rollers. All three rollers turn freely as the steel plate is moved back and forth by the operator.

Milling Rifle Barrels to Length and Centering Ends.—Fig. 7 shows the first operation on a semi-automatic rifle barrel, in which the barrel is cut accurately to length in a double-end automatic, which also center-drills the two ends. For this operation, the stock is located lengthwise in V-blocks on the work-holding units by a finger-stop on the headstock. The work is automatically clamped in the V-blocks by the operation of two motor-driven screws. The work-holding units are adjustable longitudinally on a bar in the center of the bed to suit the length of the barrel being handled. After the rifle barrel has been clamped, the

work-holding units are rocked toward the back of the machine to carry the ends of the barrel past two milling cutters. The work-holding units then rock forward to bring the barrel in line with two centering and countersinking drills, as shown. These drills automatically advance to the work and return, after which the work clamps are released. The rifle barrels reach this machine approximately 1/4 inch too long, and are milled to the desired length within 0.010 inch.

Machining Cylindrical Form on Gear Shaper.—In Fig. 8 is shown an operation that has become conventional practice in aircraft engine plants, but that may be novel to

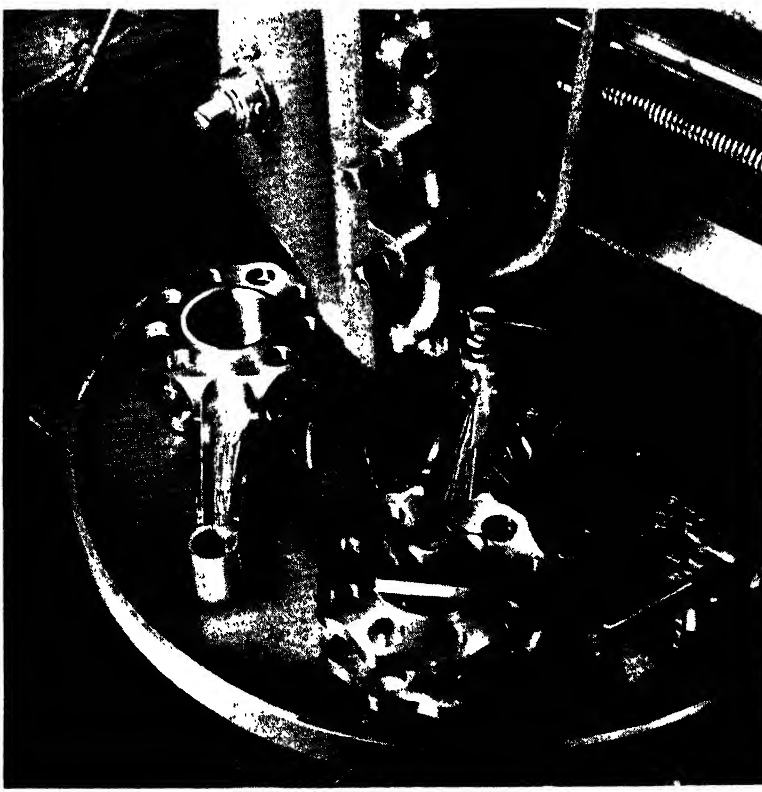

Fig. 8 Gear Shaper Machining the Wrist-pin Boss on Master Rod

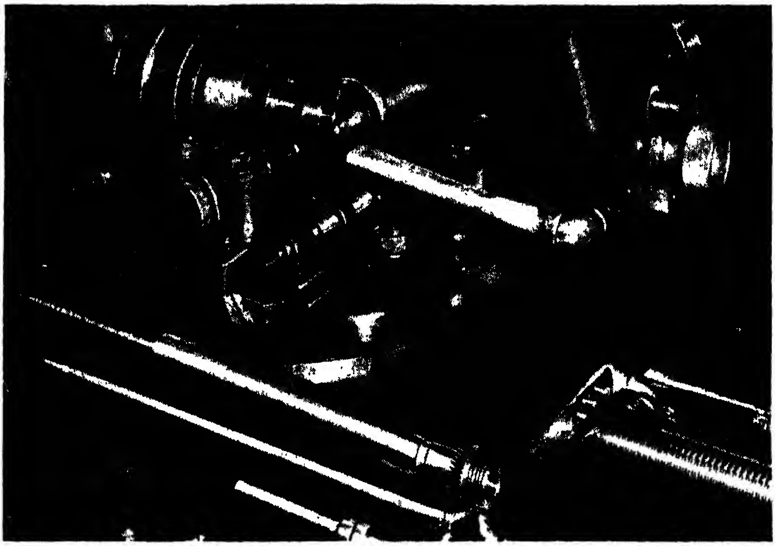

Fig 9. Hobbing Forty Serrations around the Breech End of a Machine Gun Barrel

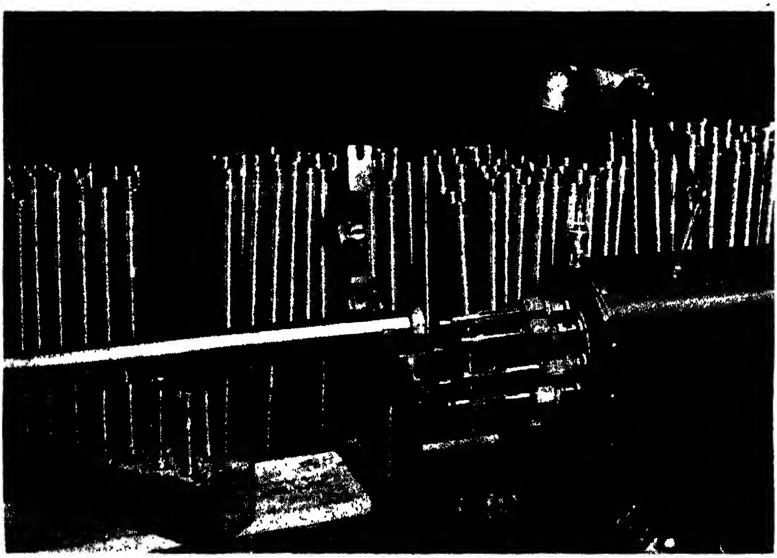

Fig. 10. Chambering of Rifle and Machine Gun Barrels is Accomplished by Using Successively a Number of Tools Mounted on an Indexing Head

production men in other industries. It consists of shaping the wrist-pin boss of master rods to a cylindrical contour on a gear shaper. The master rod is indexed slowly by automatic means around a circle of the required diameter between reciprocations of the disk-like cutter. The generating action of a gear shaper frequently is utilized for operations other than gear cutting.

Forming Serrations by Hobbing.—Forty serrations are hobbed around the breech end of machine gun barrels by the machine shown in Fig. 9. The work is slipped into the collet chuck through the left-hand end of the hollow work-spindle, and is located lengthwise by a bar gage, placed between the end of the work and the center held in the bracket suspended from the over-arm of the machine. This operation is similar in principle to cutting a spur gear by the hobbing process.

Chambering Rifle Barrel.—An important step in the production of rifle barrels consists of roughing and finishing the chamber. Six cutters, mounted on the multiple head of a machine of the type shown in Fig. 10, are used for the roughing cuts, and eight for finishing. Reaming, counterboring, countersinking, and chamfering cutters are indexed successively into line with the barrel bore, and then fed along the barrel to the required depth. The various surfaces must be true to the specified diameter and length within plus or minus 0.0005 inch. All the gages seen in the block on the bed of this machine are employed for inspecting the finished chamber.

Drilling Aluminum-alloy Pistons.—Drilling and slotting of aluminum-alloy automobile pistons are done by the four-station indexing type of machine shown in Fig. 11. The pistons are loaded at the front of the table by slipping the piston-pin holes over a plug on each fixture, seating the skirt end against a vertical face, and applying a clamp against the closed end. In the first working station at the left, two spindles on horizontal heads are fed rapidly toward each other for drilling small holes that will form the

ends of an expansion slot to be cut in the next station of the machine, parallel with the piston-ring grooves. The cutting of the slot is accomplished by means of a 6-inch diameter slitting saw on the upper tool-head of the machine. At the same time, the small-diameter saw seen above the piston in the third working station comes down and cuts a short slot that connects the long expansion slot with a hole that has previously been drilled in the skirt end of the piston.

High-speed Nut-castellating Machine.—Nuts are castellated at a high rate of speed in the machine shown in Fig. 12, which is arranged with two conveyor chains that carry the nut blanks past three slotting cutters mounted on both sides of the machine. The conveyor chains are fitted with small chucks into which the nuts are slipped by

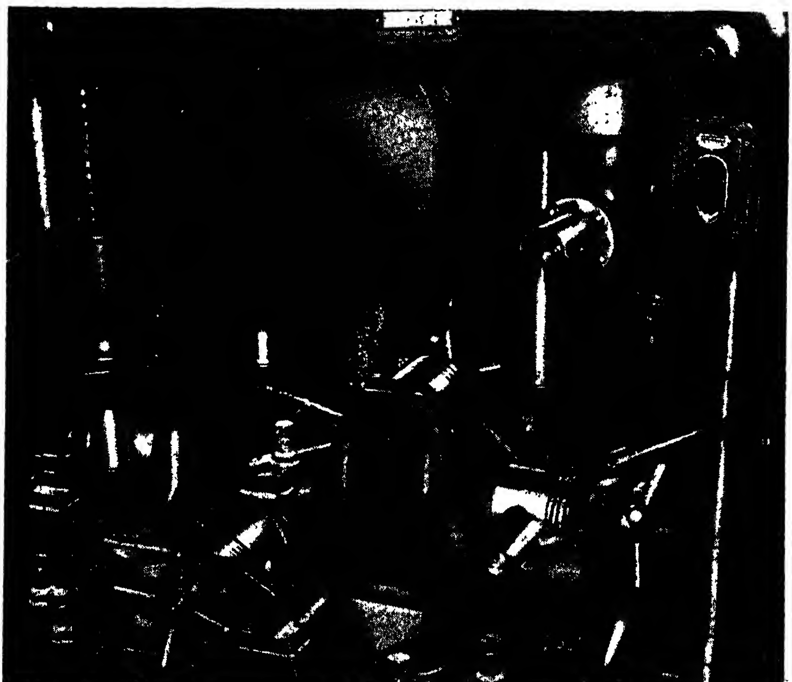

Fig. 11. Machine Designed for Drilling Two Holes and Slitting the Expansion Slots in Aluminum-alloy Pistons

an operator standing at the right-hand end of the machine, the drilled hole in the nuts being seated on studs in the center of the chucks. As the conveyor chain carries each chuck beneath the first cutter at the right, two of the castellated slots are milled. Then a finger mounted on a bar in front of the conveyor chain engages a slot in the chuck and indexes it through 60 degrees, so that it is in position for the milling of two more slots by the second cutter. Again, the chuck and nut are indexed 60 degrees before they reach the third saw, which completes the slot-cutting. The castellated nuts are automatically discharged from the chucks after they pass around the sprocket seen at the left-hand end of the machine, by a spring-actuated "knocker" which strikes a blow on each chuck on the side opposite to the nut. The saws and nuts are flood-lubricated.

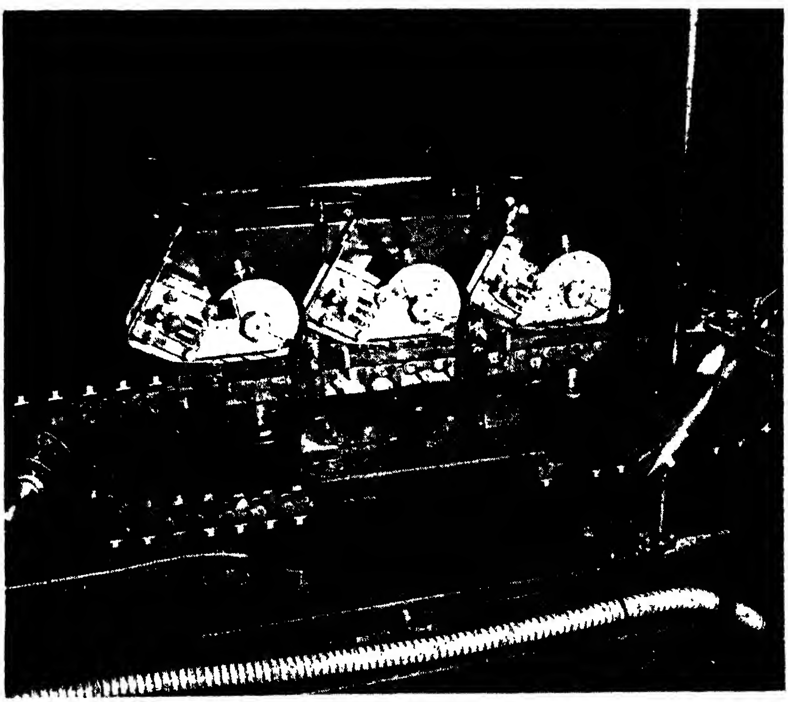

Fig. 12. Nut-castellating Machine Arranged for Cutting All Six Castellated Slots in One Passage beneath the Cutters

Forming Beads on Ends of Tubes.— A special machine designed for forming a bead in the ends of tubing is shown in Fig. 13. Typical examples of work may be seen lying on the table drawer, some of the parts being cut away at one end to illustrate the appearance of the beads on the inside of the tubes. Either stainless-steel or aluminum tubing can be handled. The tube is placed between the split dies and clamped in position. Only one die half is seen in the chuck, the other half lying on top of the machine. Extend-

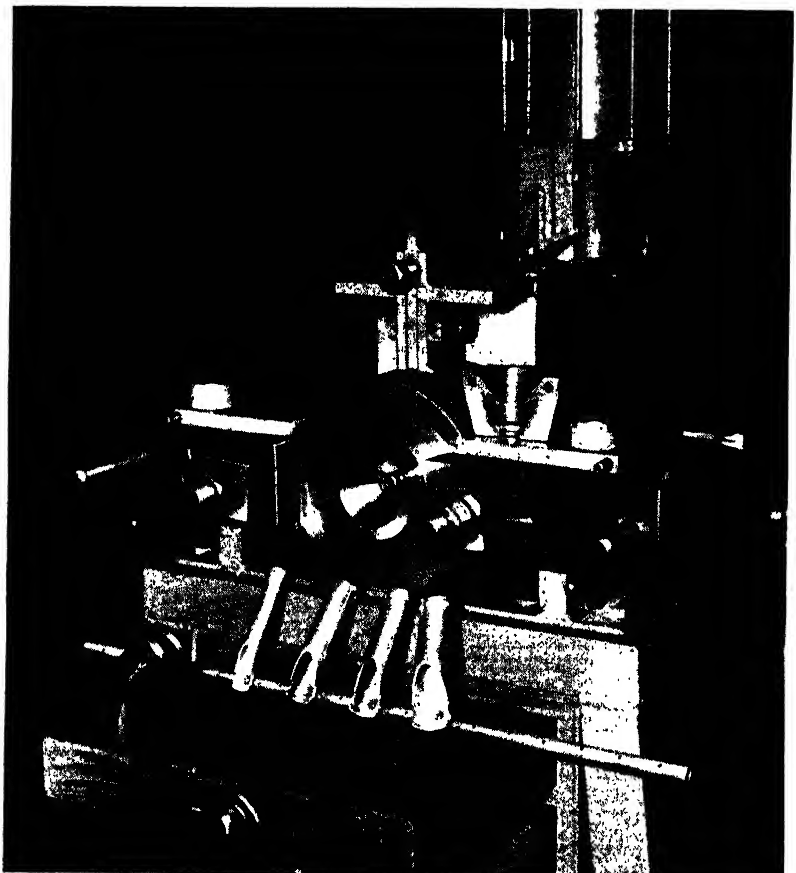

Fig. 13. Special Machine Designed for Producing Beads in the Ends of Tubes through the Expansion of a Rubber Ring

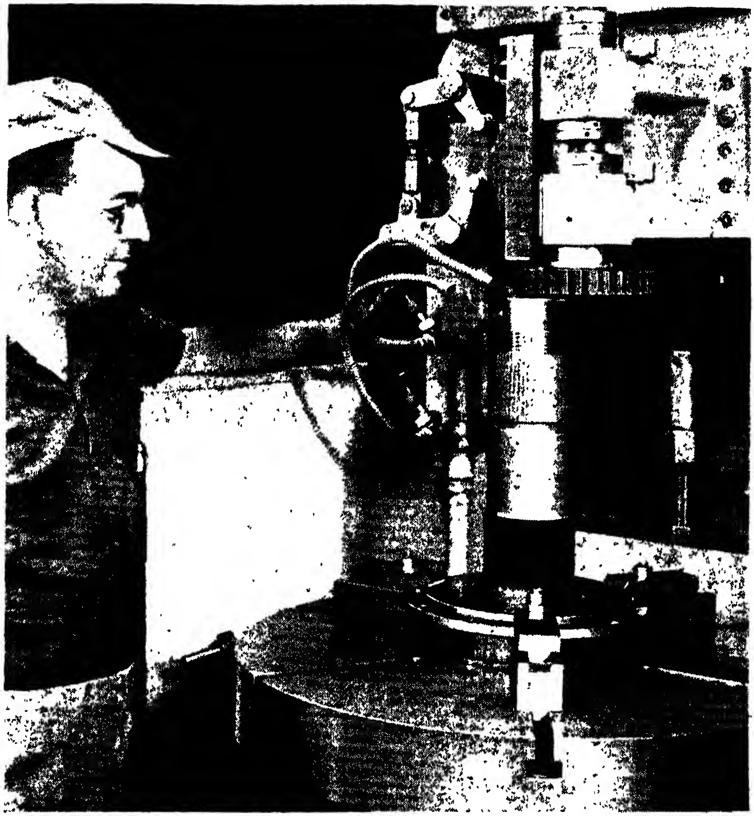

Fig. 14. Machining the Serrations around a Tapered Hub

ing through the center of the die halves, and therefore into the end of the tube to be beaded, is an air-operated ram which carries a ring of rubber between sliding and stationary members. When the sliding member of this ram is pulled back with the application of air pressure, the width of the rubber ring is compressed with the result that the periphery is expanded within the tube. This expansion of the rubber forces the outer wall of the tube into the cavity in the die halves and thus forms the bead. One of the die halves is then removed to enable withdrawal of the beaded tube.

Cutting Serrations Around a Sprocket Hub.—Twenty-two fine teeth or serrations are machined around the bore of large tractor sprockets and around the hubs that are assembled with the sprockets. Fig. 14 shows the method of cutting the serrations around the hub. This operation is performed on a special machine equipped with a reciprocating circular cutter that indexes one tooth after each

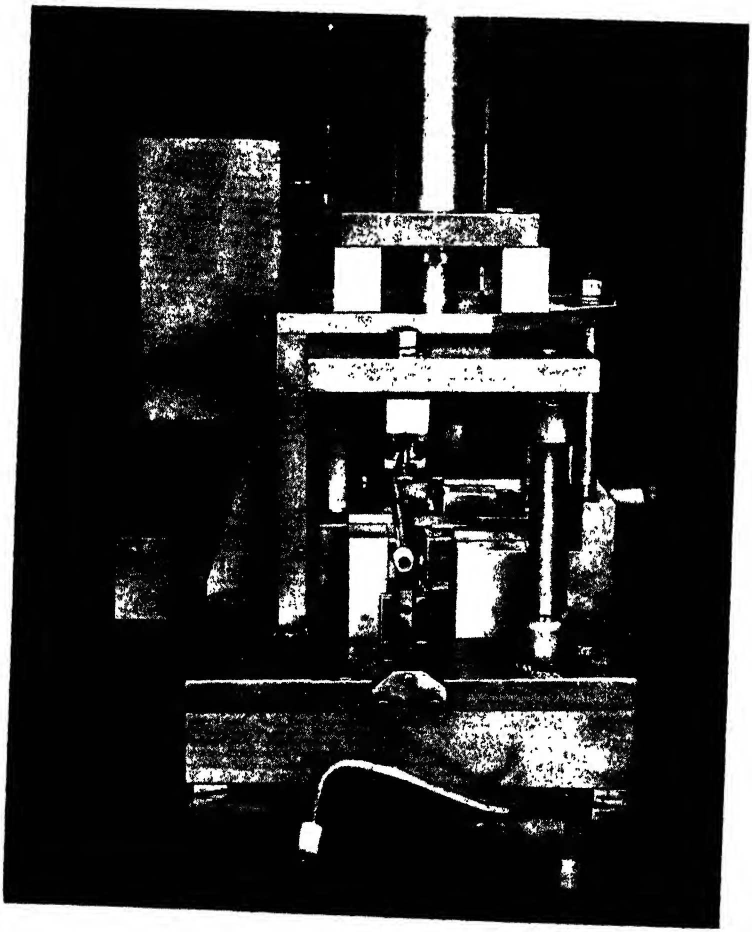

Fig. 15. Hydraulically Actuated Machine Used for the Automatic Bending of Tubing into a Variety of Shapes for Use as Oil-pump Inlet and Outlet Tubes

complete revolution of the hub. Each successive tooth on the cutter cuts the grooves deeper. When the cutter has been indexed eleven times, or half way around, the operation is completed. The next hub is machined with the teeth on the other half of the cutter. The serrations are formed on the tapered portion of the hub, and so the work is tilted correspondingly on the fixture of the machine, the taper being about 1 1/2 inches per foot. The spacing of these serrations must be accurate within plus or minus 0.0002 inch, with no accumulated error on the entire periphery, and equally close tolerances are specified for the shape of the serrations. This accuracy insures the desired fit with the serrations in the sprockets.

Machine for Bending Oil-pump Tubes.—A small machine for bending oil-pump inlet and outlet tubes to the required shapes is illustrated in Fig. 15. This machine makes four bends in a piece of tubing, as shown by the example lying on the bench in front of the machine. The straight piece of tubing with threaded fittings assembled on the ends is placed in this machine as shown. The tubing is first clamped and then bent to the desired shape as a series of slides is moved horizontally and vertically against the tubing through oil pressure from the overhead cylinder. The horizontal slides are actuated by the descending of bars mounted on the plate that is attached to the hydraulic piston. This plate is guided in its vertical movements on pilot-bars that extend upward from the fixture base. Springs return the various forming slides to their normal positions when the hydraulic piston again moves upward.

Machine Equipped with Dies for Making Rifle Hand-guard Ferrules.—The "dieing machine" shown in Fig. 16 is arranged for producing rifle hand-guard ferrules. Sixty ferrules are made per minute, or approximately 21,000 during an eight-hour day, allowing time for feeding new coils of stock through the machine, etc. The strip stock, fed into the right-hand end of the machine, passes over a nine-step progressive die. In the first die a small hole is pierced, as

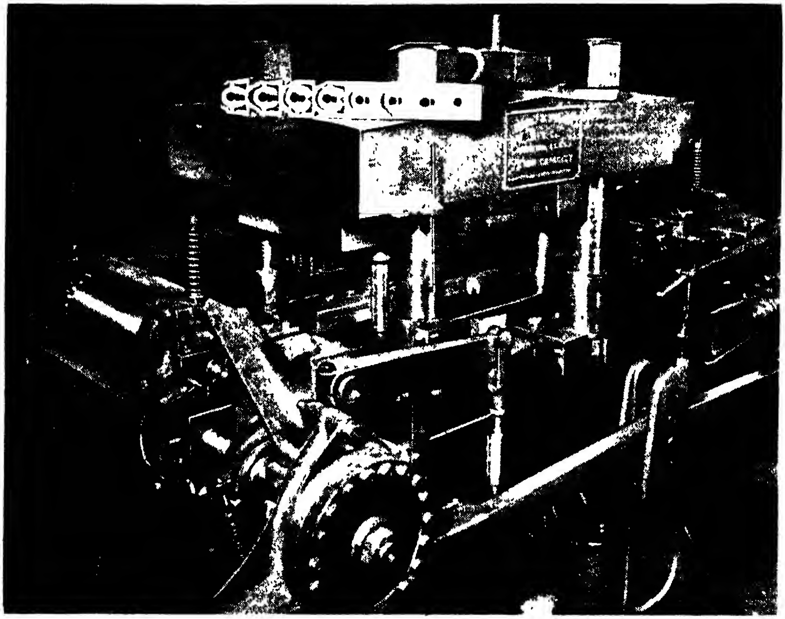

Fig. 16. Dieing Machine Equipped for Producing Hand-guard Ferrules at an Average Rate of 21,000 Pieces per Eight-hour Day

seen at the right-hand end of the strip that lies on top of the machine. In the next die this hole is expanded in diameter and a 45-degree edge is formed around the hole. Then a rectangular slot is blanked, the slugs from the operation being raised into a bin at the top of the machine. This method is necessary because any burrs on the part must point upward during the succeeding steps of the operation.

The next die cuts a trimming slot around one side of the pierced hole, a pilot being entered into this hole to insure accurate location of the stock in this position. The distance to the next die was made twice the distance between preceding dies in order to insure required die strength and to guard against stretching of the weakened stock. In the next die, the stock is blanked on the opposite side of the pierced hole and slotted, so that the ferrule is now held only by narrow strips on opposite sides. The ferrule is partly formed in the next die (while the pierced hole is

located from a pilot), and finish-formed in a similar die. Two ear-like depressions are next formed, after which the part reaches the final die that severs it from the stock and pushes it down through the die and out of the machine.

Forming and Piercing Sheets with Hydraulic Press.—The three-column hydraulic press illustrated in Fig. 17 is equipped for forming and piercing operations on aluminum and steel sheets in an airplane factory. These operations are performed over Masonite and steel forms. The operation differs from customary procedure in that a circular work-platen is revolved by power around the front column of the press to carry the blanks of work and their dies beneath the ram and to bring the finished pieces with their

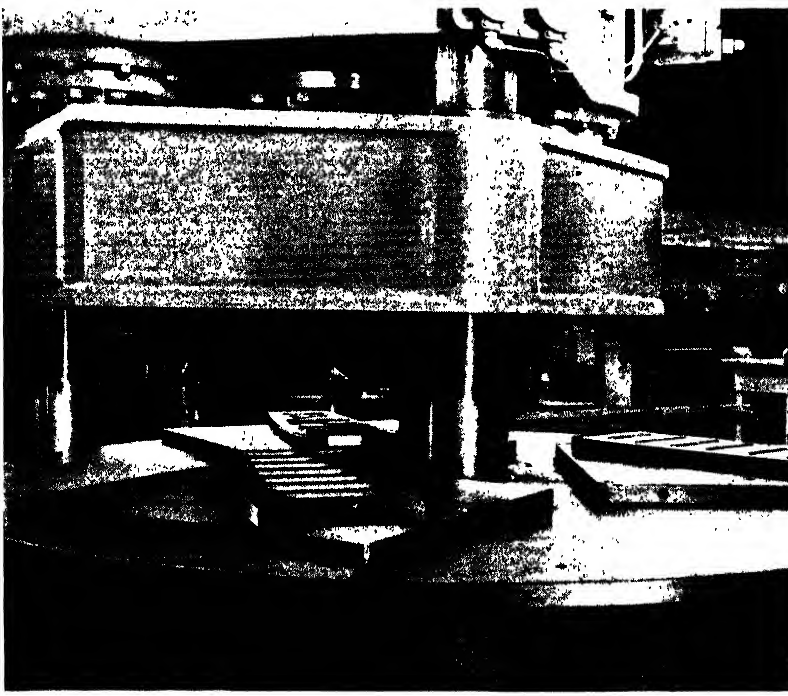

Fig. 17. Close-up View of Three-column Hydraulic Press which is Equipped with a Rotary Table that Permits Reloading of Work and Dies while the Press is in Operation

forms in front of the ram. While each operation is in progress, new work is being loaded on the portion of the platen that is outside of the press ram. This machine works entirely automatically and keeps two operators busy reloading. As the press ram rises after each operation, the rotary table automatically swings new work into position. With this arrangement, no time is lost in loading and unloading. The operation is also unusually fast, because the press ram moves at a speed of 640 inches a minute. Safety of the operator is another important factor, it never being necessary for the men to reach beneath the press ram. The close-up view shows three forms on the rotary platen. The press has a rating of 1200 tons.

Offset Die for Crimping Structural Angles.—Many pieces of aluminum-alloy structural angles must be crimped or

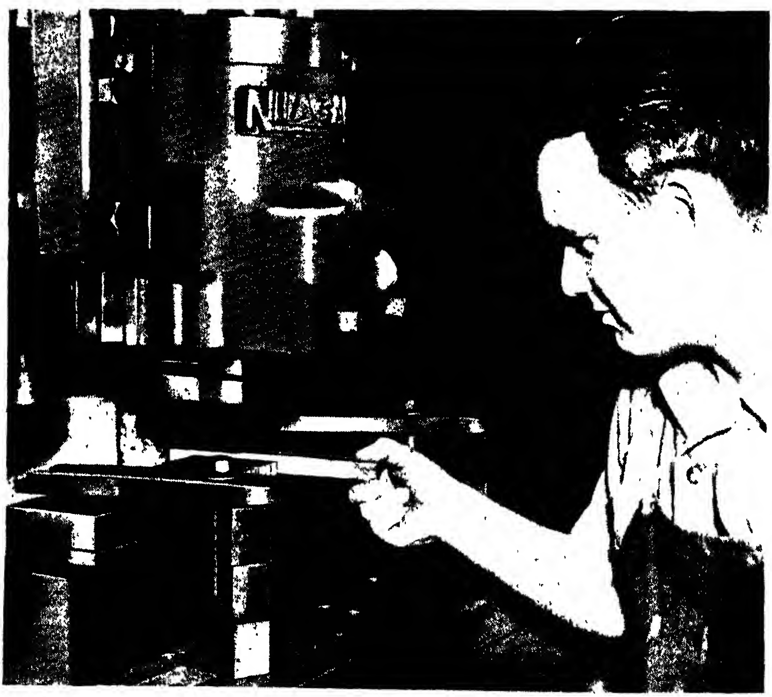

Fig. 18. Offset Die for Crimping Structural Angles

offset slight amounts in order to span over metal sheets or other structural shapes in airplane assembly. The offsets must be produced at various angles in relation to one leg of the structural member. To meet these requirements, a joggling or offset die of the type seen on the press shown in Fig. 18 was designed with a series of slots that spread out in a fan shape from the front side of the die, so as to provide a large number of angular positions in which the work-pieces can be located for the crimping operation.

One leg of an angle to be crimped is merely seated in the proper slot. When the press is operated, two flat spring-backed blocks attached to the ram descend and bend the back end of the angle down over an offset on the die. This offset is obtained by making the die in halves lengthwise and shimming up the front die half the required amount of the offset. The slots that extend across the die-block in fan-shaped fashion are spaced for each 10 degrees of angle. Dies of this design are made to accommodate various amounts of offset from 0.040 to 1/2 inch.

Pneumatic Hammer for Sheet Forming Operations.—The hammer or press illustrated in Fig. 19 applies pneumatic pressure for forming sheet-metal pieces between Kirksite and lead dies. Machines of this type are widely used in airplane factories. The press shown has a die area of 60 by 68 inches, and is equipped for the production of a difficult part, which has a square depression in the center and a series of corrugations. The piece is 34 inches long by 20 inches wide when finished, and the corrugations are 1 1/4 inches deep. Both Alclad aluminum-alloy and stainless-steel sheets are formed by this equipment. The press is installed on an I-beam foundation, and is equipped with twelve spring type shock absorbers to take up the heavy blows.

Tube Bender Equipped with Angle-indicating Attachment.—The tube-bender, Fig. 20, is equipped with an angle-indicating attachment or protractor that facilitates the making of bends in various planes with respect to each other. A typical operation is shown. The rear end of the

tube is fastened to one of the protractors, which is mounted on a carriage that runs along the center of the bench, the protractor sliding on a mandrel bar. The mandrel bar extends from the far end of the bench to the bending blocks, so as to support the tube from the inside and thus prevent collapsing of the wall. Bends are made by gripping the tube between stationary and movable blocks having grooves of the required dimensions to suit the tube, and then operating a ratchet wrench at the front of the machine to swing

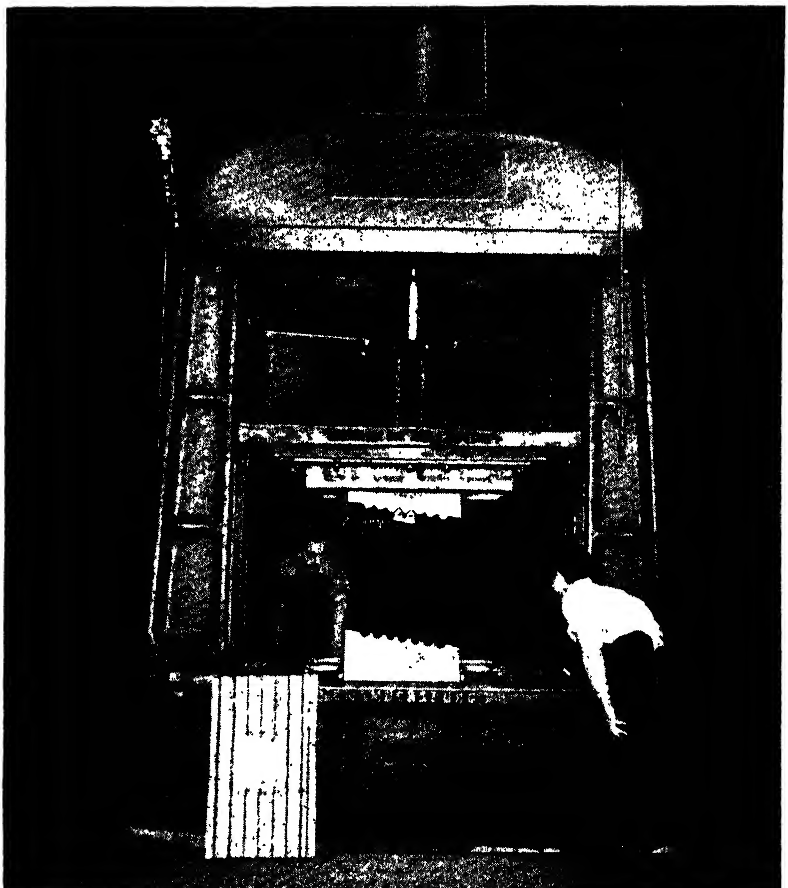

Fig. 19. Pneumatic Hammer which Forms Pieces from Aluminum-alloy and Stainless-steel Sheets between Kirksite and Lead Dies

the movable bending block about its pivot. By observing the graduations on the dial of the protractor fastened to the bending block, the operator can readily determine when to stop bending. For the next bend, the operator loosens the right-hand bending block or jaw, pulls the tube through the bending blocks the required distance between the points of tangency of the bends, adjusts the protractor on the rear end of the tube if the next bend is to be made in a different plane from the first, reclamps the right-hand bending block, and proceeds as before. Charts are kept of all bending operations to be performed in quantity, so as to permit quick duplication of bent tubes. A scale extends the length of the table in the center, so that the operator can readily determine the correct positions of the protractor carriage for various bending operations.

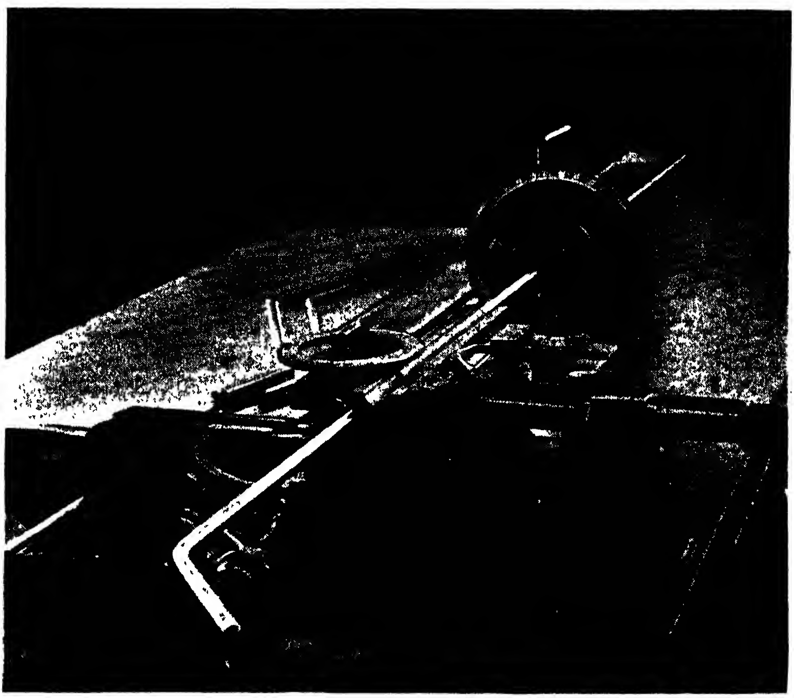

Fig. 20. Tube-bending Machine Equipped with Angle-indicating Attachments

Three-station Machine for Boring and Thread-cutting.—Unusual tooling developed for boring and threading conical bronze bushings is illustrated in Fig. 21. In this operation, which is performed in a three-station machine, a modified buttress thread with a lead of only 0.023 inch is cut across a surface 9/16 inch wide. Though the tools are fed through the work by hydraulic action, the error across these threads is very slight.

The work-pieces are located on the hydraulic chucks from involute surfaces on two internal projections that may be seen on the parts lying at the right end of the tool carriage. They are gripped by clamps that pull against these projections. The chuck spindles are positioned at an angle of 7 degrees 55 minutes, so as to bring the conical surfaces to be machined into line with the movement of the tool

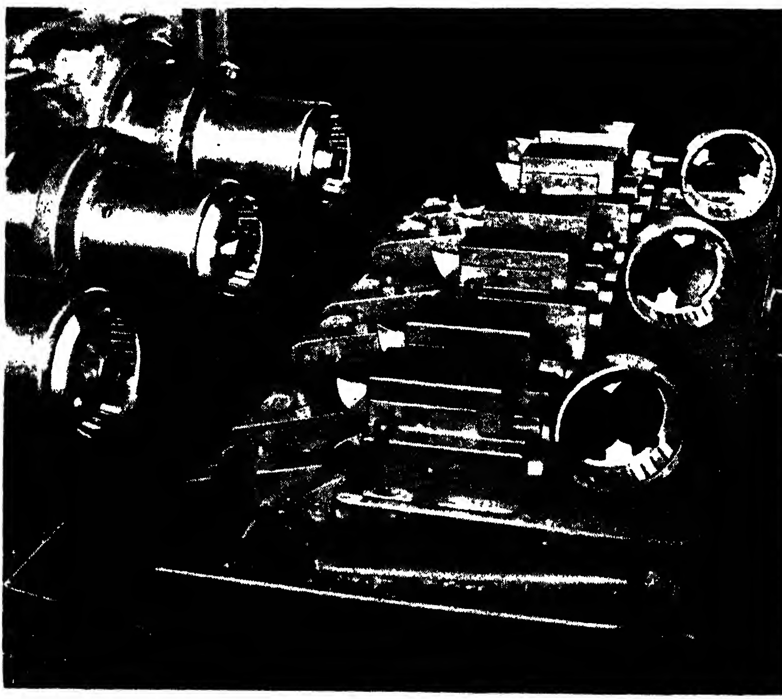

Fig. 21. Tooling for Boring and Threading a Tapered Surface in Three Synchronizing Drums for Automobile Transmissions

carriage. Each of the stations on the tool carriage is equipped with two tools, one for boring and one for single-point threading.

In operation, the tool carriage feeds to the left for boring all three parts simultaneously, then moves slightly toward the front of the machine to relieve the cutters from the work, returns to the right, indexes forward to bring the second tool of each group into line with the work, again feeds to the left for threading the work-pieces, moves slightly forward to relieve the threading tools, traverses to the right for withdrawing these tools, and indexes the tools back to the starting position.

Attached to the front of each tool-block are arms that carry hardened cylindrical plugs which are swung upward for locating the boring and threading tools when they are replaced. It is the practice to employ feeler gages between these plugs and the tools. The plugs can be adjusted sidewise on their holders to suit larger or smaller work diameters, and the tool-blocks can be turned toward or away from the setting plugs by loosening clamps and turning the graduated heads of screws. Tungsten-carbide tools are employed in this operation.

Examples of Spot Welding.— In modern manufacturing practice, welding equipment frequently is arranged to suit a given class of work, especially when quantity production is required for duplicate parts. Some examples follow. Fig. 22 shows a spot-welder provided with a roller electrode which makes a series of spot-welds, superimposed on one another, as the work is moved under the roller, to obtain an air-tight seam. The piece being operated on is part of the duct of an air cooler for airplane applications. It is made from sheet duralumin.

Sheets of aluminum alloy are "sewed" together to obtain lengths required for covering airplane wing surfaces by the spot-welding machine shown in Fig. 23. The sheets to be joined are laid on a spacing table which is advanced in short increments sidewise past the electrodes through a trip mechanism operated by the man at the left, so as to obtain a continuous weld. As the sheets are joined, they

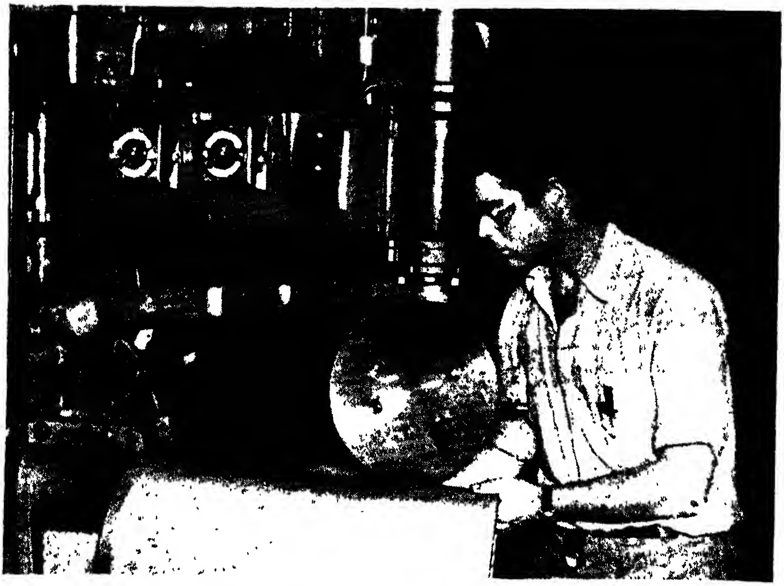

Fig. 22. Spot-welding with Roller Type Electrode

Fig. 23. "Sewing" Sheets of Aluminum Alloy with Spot-welder

are rolled on the drum at the left-hand end of the spacing table. This table can be manipulated for welding from either side of the sheets.

Welding Disks to Base Ends of Shells.—Fig. 24 shows how thin disks of sheet metal are welded on the base end of 3-inch, 90-millimeter, and 105-millimeter shells. This operation is performed on roller type spot-welders. These machines are equipped with two roller electrodes which ride on the thin disk as the shell revolves in the fixture. By providing two electrodes, the disk is completely welded

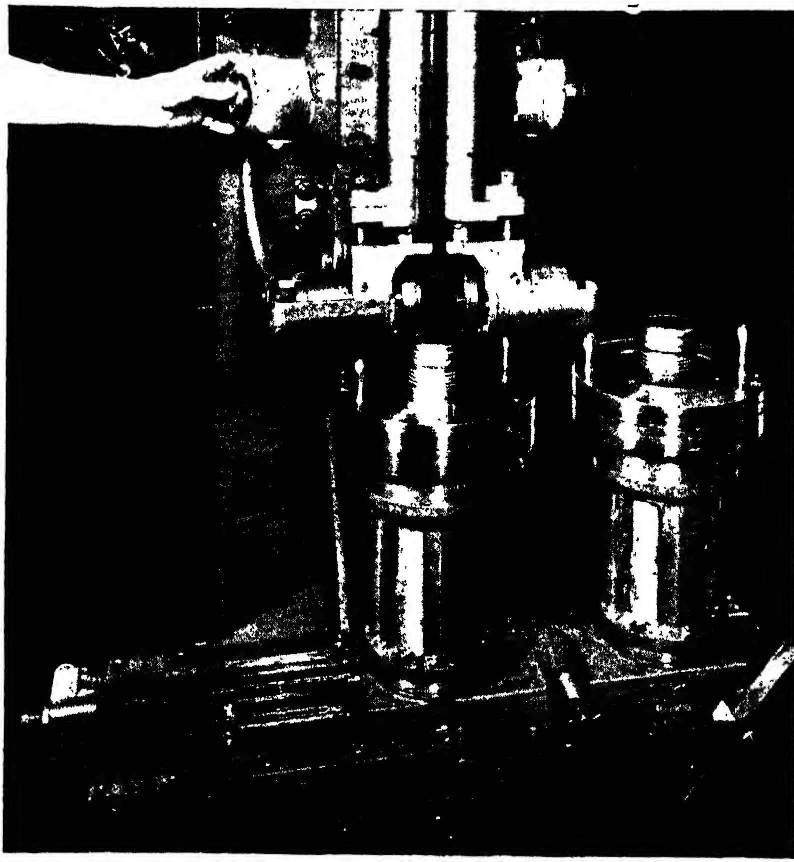

Fig. 24. Roller Type of Spot-welding Machine Used to Weld a Sheet-metal Disk on Base Ends of Some Types of Shells

around a circle with only one-half revolution of the shell. This disk is a seal for minute cracks in the shell that might admit gas to the inside of the projectile in firing.

Two work fixtures are provided on a slide at the front of the machine, so as to enable the operation to be performed practically continuously, with little time lost in reloading. The slide is moved quickly to the right or left by the handle seen at the right in the illustration, which is connected by a link to a pin in the center of the slide.

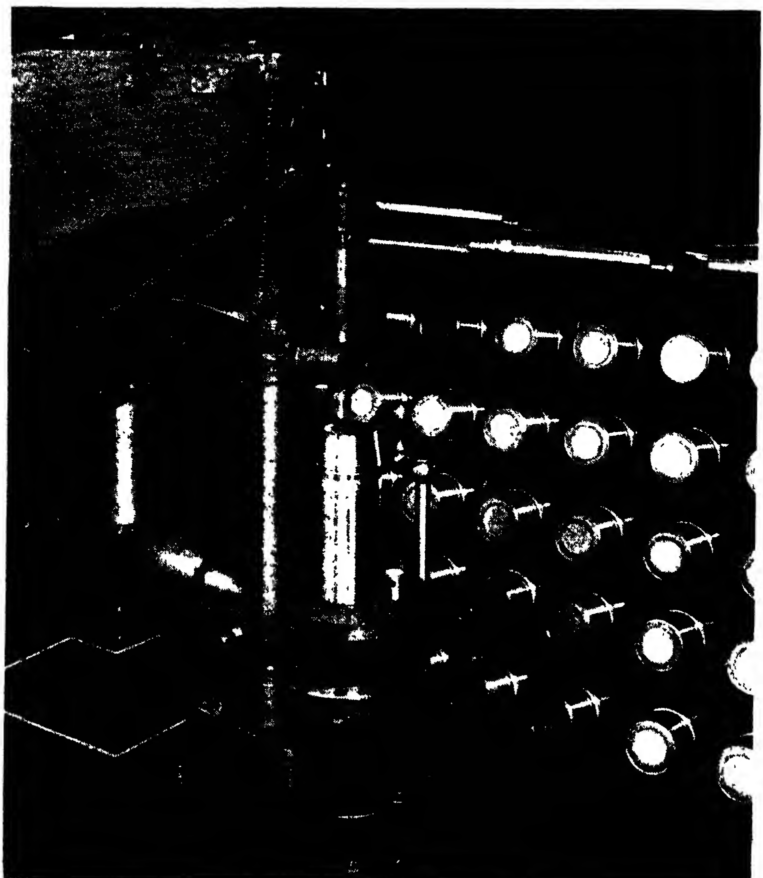

Fig. 25. Automatically Spot-welding a Thin Sheet of Steel to the Base Ends of Artillery Shells

Another machine arranged for welding a thin disk of steel to the base or closed end of shells is shown in Fig. 25. The illustration shows this operation being performed on a spot-welder, arranged with a mechanism that automatically indexes the shell between successive vertical strokes of the electrode. An air-tight weld is obtained by overlapping the welding spots.

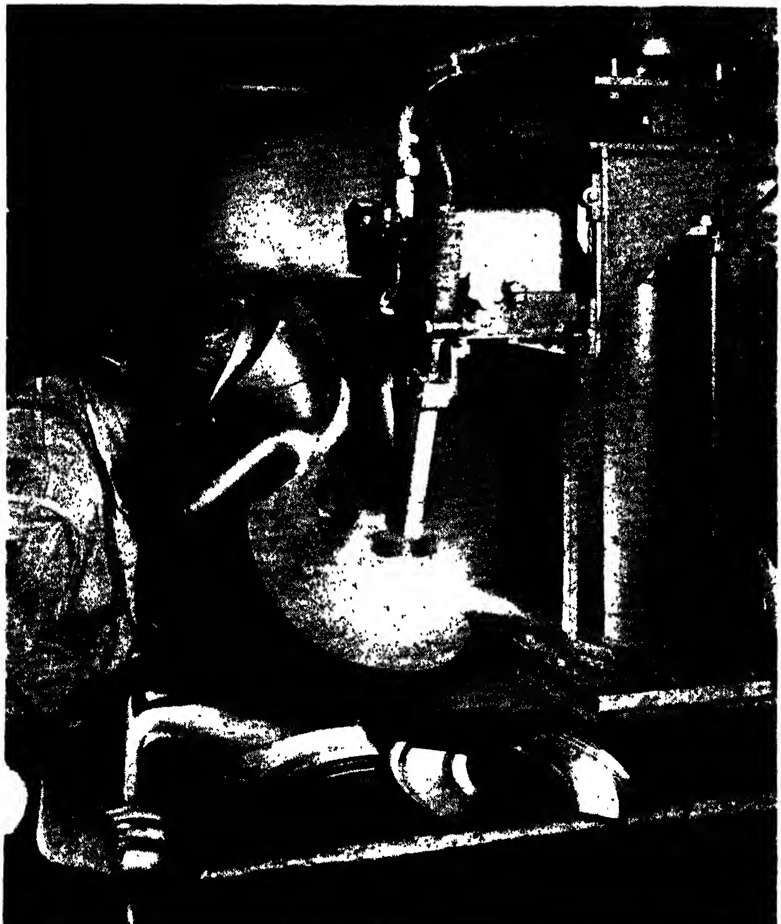

Fig. 26. Two Pieces of Sheet Steel that Form a Magazine are Joined by Atomic Hydrogen Welding

Atomic Hydrogen Welding.— The two pieces of sheet steel seen in the foreground of Fig. 26 are welded together to make a cartridge magazine. One of the welded magazines is also shown. These pieces must be welded together with great care, as there is an allowance of only 0.010 inch across the width of the magazine, and the welding must be performed without excessive flash and without bubbles in the weld. Also, good penetration of the weld is essential.

The operation is performed with the atomic hydrogen arc-welding equipment seen in this illustration. Four pieces to form two magazines are loaded at one time into simple jigs in such a way that the edges to be welded just touch each other along their full length. These jigs are then mounted, one at a time, on the work-head of the machine, as shown, the work-head being revolved to carry the jig beneath the welding head. There are two positions of the welding head, so that the electrodes can be applied on both sides of the jig for welding the two sides of the magazines.

With this equipment, even seams are produced along both the inside and outside of the welded edges. When the magazines are buffed, it is almost impossible to see where the two pieces of sheet metal were joined. The average production is 450 magazines in eight hours.

Machine for Arc-welding Flanges to Trailer Axles.—Four automatic arc-welding heads are applied simultaneously by the welding machine shown in Fig. 27, for welding two flanges to the tubular members of trailer axles. The axle is revolved beneath the welding heads by a chuck that grips it at the left end. The welding heads are so mounted on slides that they can be tilted into the required positions relative to the work. The slides can be moved longitudinally on a rail at the back of the machine and locked in desired locations. This machine has a rating of 750 kilovolt-amperes.

Automatic Welding by "Unionmelt" Process. — The "Unionmelt" electric welding process has been found particularly advantageous in shipbuilding or similar work, because it enables high-quality welds to be made at compara-

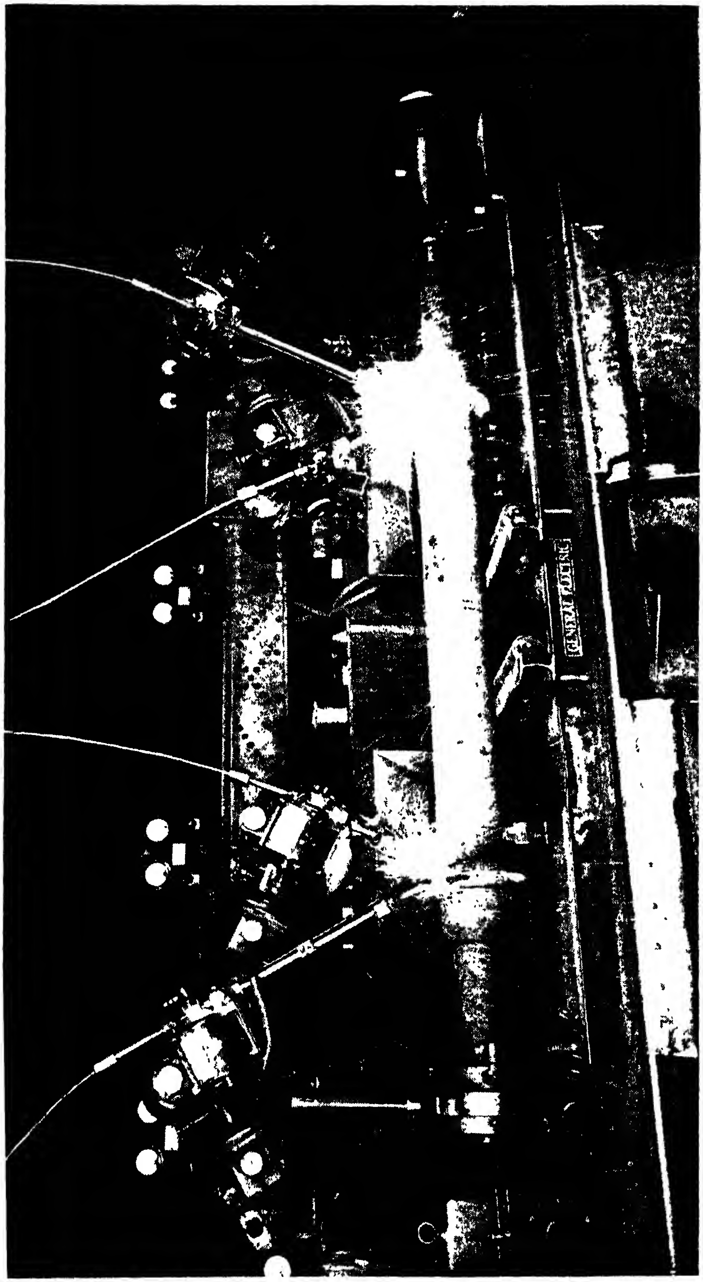

Fig. 27. Arc-welding Two Flanges to Trailer Axles by the Simultaneous Application of Four Automatic Welding Heads

tively fast speeds by operators who have had relatively little training in welding. As the process is completely automatic, the quality of the weld is not dependent upon the human element. In this process, heat is generated by the passage of electric current from an electrode to the plates being joined. The heated end of the electrode is

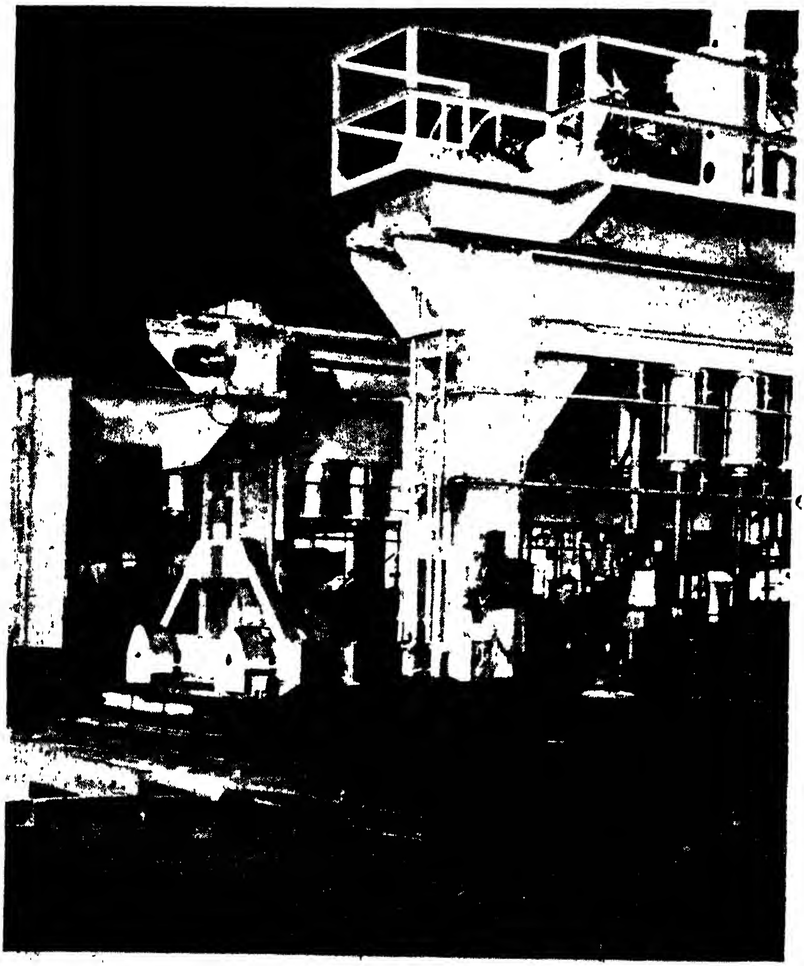

Fig. 28. Large Three-station Welding Machine used in Ship Construction for Automatically Welding Structural Steel Stiffeners to Both Sides of Ship Plates

kept completely covered by a highly resistant granulated material or welding composition known by the trade name "Unionmelt."

The entire welding action takes place beneath this granulated material without any visible arc and without sparks, spatter, smoke, or flash; hence, the welders need no protective helmet or goggles. Within the layer of Unionmelt, an intense, concentrated heat is generated, so that the bare-metal electrode and the edges of the steel plates to be welded are melted and fused. Molten metal from the electrode is thoroughly mixed with the melted base metal to form the weld. While the weld is being made, a sub-surface layer of the granulated material melts and floats as a liquid blanket over the molten weld metal.

The granulated material, when molten, makes possible the use of unusually high current densities, which permits rapid generation of intense heat for melting the steel plates. The molten granulated material is a good heat insulator, and thus concentrates the heat in a relatively small zone. It acts also as a cleanser for the weld metal, washing the metal which melts from the electrode and absorbing impurities from the fused base metal.

This welding process is fully automatic, being applied either by large, permanently installed machines (Fig. 28), or by comparatively small, portable equipment that is usually guided along the work on a suitable track, as seen in Fig. 29. The bare welding rod is continuously drawn from a reel and fed by the welding head into the welding zone. The granulated material is automatically delivered through the welding head, and progressively laid down along the seam being welded, so as to cover completely the rod end.

At the beginning of an operation, a special "fuse," such as a wad of steel wool, is used to start the weld, since the granulated material is not a conductor of electricity when it is cold. After the steel wool has been covered with the granulated material and the welding current has been turned on, enough heat is immediately produced to melt the steel wool and the adjacent layer of granulated material, thereby enabling the welding operation to begin.

The granulated material is progressively fused by the heat that is generated as the welding operation progresses.

Since only part of the granulated material is fused during welding, the unfused material is picked up either manually or by the use of a suction hose, which returns it to a hopper to be used over again. The portion of the granulated material that has become fused solidifies behind the welding zone, and upon cooling, contracts and detaches

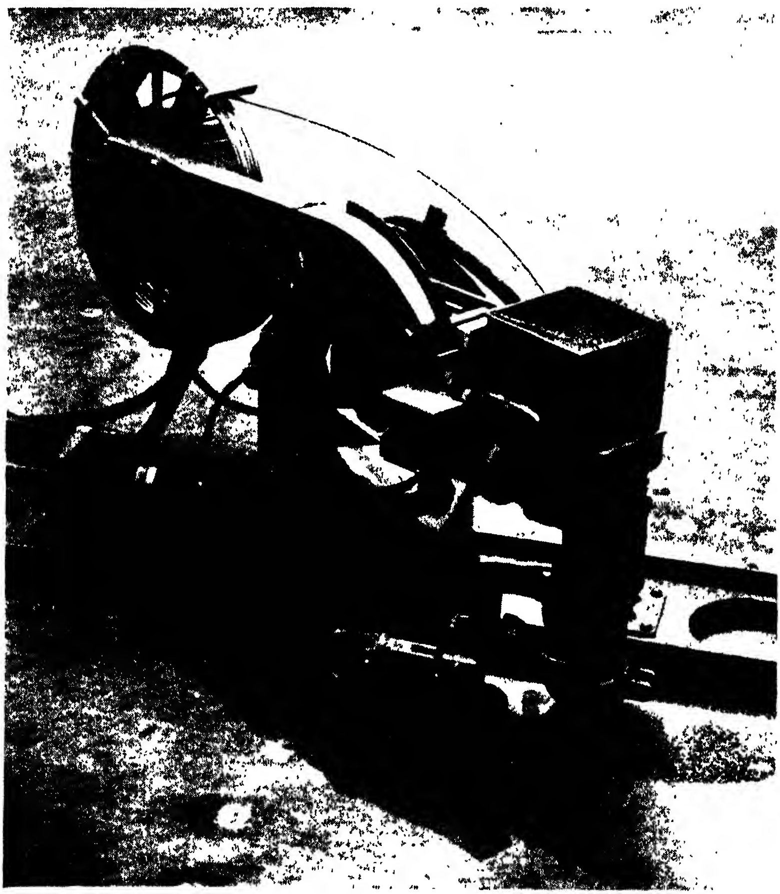

Fig. 29. In Unionmelt Welding, the Electrode is Completely Covered by a Granulated Material, and the Operation is Performed without any Visible Arc, Sparks, or Smoke

itself from the welded plates, exposing the clean, smooth weld.

Welding voltage, electric current, speed of operation, and rod feed are all automatically regulated by means of electrical controls, and depend upon the kind of material being welded, its thickness, the type of prepared edges on the plates to be welded, the desired depth of fusion, and the shape and reinforcement of the weld. Once the weld is started, the operator merely pushes the buttons or adjusts controls.

Butt, fillet, and plug welds can be made. In making butt welds with one pass, when complete penetration is desired, some support must be provided under the seam to prevent the fluid metal from running out of the bottom of the joint. A copper bar, a sliding copper shoe, and a trough filled with Unionmelt material have all been successfully used for backing up butt welds. When the granulated material is used as a backing, a reasonably smooth bead can be obtained on the bottom of the weld, similar to that on the top surface.

For much ship work, however, no backing is used for butt joints, the weld being made in two separate operations. A partly penetrated weld supported by the unfused portion of the joint is first made from one side and the finishing weld, supported by the first weld, is made from the other side. When the pieces to be welded can be turned over, so that both portions of the weld can be made in the "down-hand" position, Unionmelt welding is used for both portions of the weld. When turning is impractical, an "overhead" manual arc-welded deposit can be used as backing for the main Unionmelt weld.

In the construction of ships, Unionmelt welding is employed both for the prefabrication of structural sections in the shop or assembly yard, and for the assembly of the various sections on the shipways.

The thicknesses of plate that are Unionmelt-welded in prefabricated units vary from 1/4 inch on plates for casings to 9/16 inch for plates used as tank tops, and the fillets vary from 1/4 to 1/2 inch. Experience has shown

that, by the use of portable equipment, speeds of from 18 to 28 inches per minute are obtainable when welding plates of these thicknesses.

Electric Furnace for Copper Brazing. — A reducing-atmosphere furnace for copper-brazing a large variety of parts is illustrated in Fig. 30. The parts to be brazed are first pressed on each other to a tight fit, and then a ring of pure copper wire is placed beside the joints to be brazed. The parts are next laid on the chain link conveyor belt of

Fig. 30. Tubes, Levers, and Brackets are Copper-brazed Together as They are Carried through Reducing-atmosphere Furnaces of the Electric Heating Type

the furnace, as seen in the illustration. Maximum production of the furnaces is obtained by nesting small parts within the larger ones. The furnace handles 7 1/4 pounds of work per square foot of conveyor belt every eight hours. The over-all length of the furnace is about 38 feet.

In passing through the furnace, the work first enters a heating zone approximately 8 feet in length, which is electrically heated to a temperature of 2040 degrees F. It then passes through a cooling section 30 feet in length, 55 minutes being required to traverse the entire length of the furnace. The desired atmosphere is obtained in both the heating and cooling zones by the use of one part of city gas in combination with six parts of air. The water vapor content is removed before the resulting slightly reducing atmosphere is carried into the furnace. Running water flows between the outer and inner chambers of the cooling zone to keep the temperature low.

About thirty different assemblies are brazed together. These include steering-knuckle support-arm brackets, clutch-release shafts, clutch-operating shafts, and transmission remote control levers. Generally speaking, an assembly consists of one or more bent levers or brackets attached to a piece of tubing which serves as a bearing for a shaft or as a shaft. These parts are thoroughly washed before they reach the brazing furnaces. The copper-brazing wires are placed on the tubes beside the levers or brackets that are to be attached to them.

In the passage of the work-pieces through the heating zone of the furnace, the copper wire melts and flows between the tubes and the other pieces and forms joints that have proved to be stronger than the parent metal itself. This strength is derived from the alloying of the copper with the steel of the parts being brazed together. Whether a joint is of the required strength or not can be determined by merely observing if the copper has flowed all around the tube through to the opposite side of the pieces being brazed. This permits an unusually positive method of inspection. Parts brazed together by this practice can be cyanide-hardened after the brazing operation, because the harden-

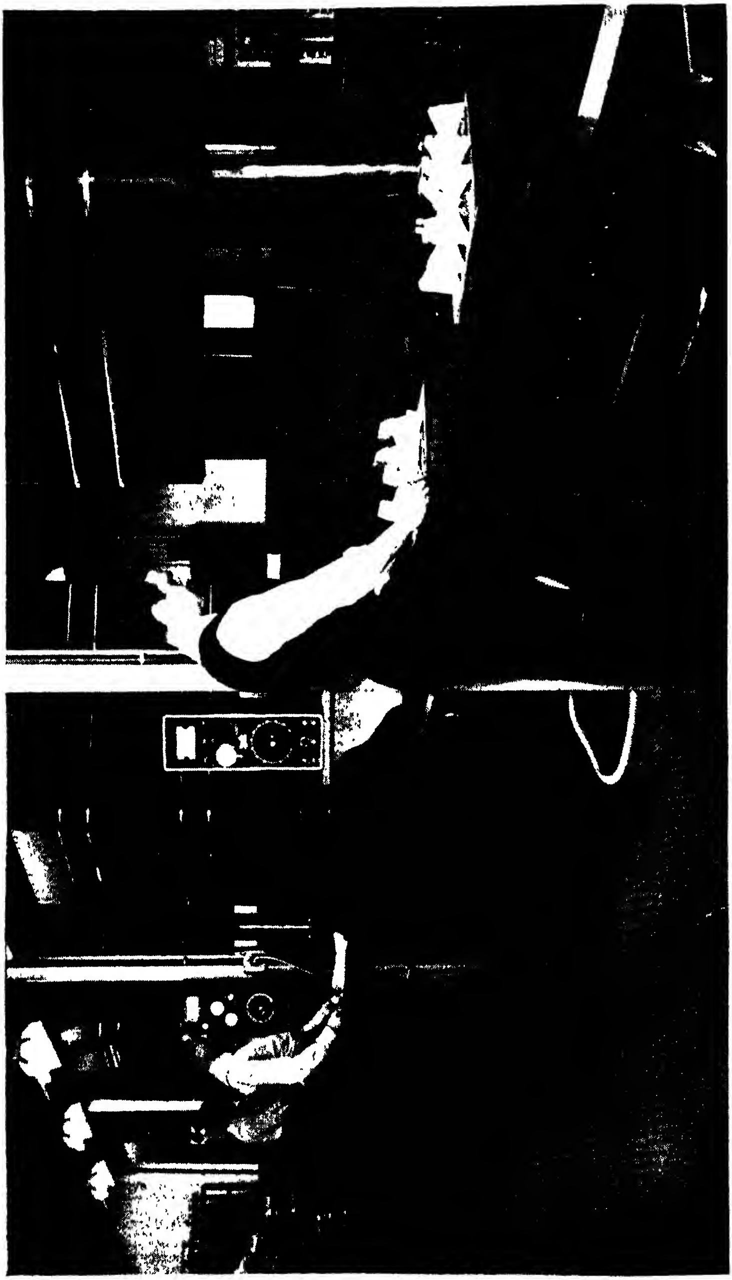

Fig. 31. Four X-ray Machines which are Completely Automatic in Operation and Enable 20 000 Pieces of Work to be Inspected by the X-ray Process in an Eight-hour Day

ing is performed at about 1550 degrees F., which is below the melting point of copper.

X-ray Inspection of Castings and Forgings. — Fig. 31 shows the X-ray inspection equipment used in an airplane plant. All aluminum castings and forgings that are highly stressed in service and 10 per cent of all other aluminum castings and forgings are inspected by this equipment to detect any flaws. Four automatic X-ray machines perform this inspection on a production basis, these machines being capable of X-raying at least 20,000 parts in an eight-hour day.

The castings and forgings to be X-rayed are brought to these automatic machines on rack type trucks, and are placed on a sliding table, as seen at the left of the machine at the right. Each table is provided with two platens, one of which can be loaded while the other is in position for X-raying work already loaded. When the preceding inspection has been completed, the sliding table is automatically moved into place under the X-ray lamp within the hood that is seen raised. The hood descends over the work, the X-ray photograph is taken, the hood is lifted again, and the work is moved from under the X-ray lamp, all automatically. The work-table moves alternately to the right and left of the X-ray lamp. A negative is made every minute on the average, usually with a number of parts in the exposure.

These automatic X-ray machines are used principally on light aluminum pieces, whereas bronze and steel parts, welded work, and heavy castings are sent to other X-ray machines of greater capacity, located in separate rooms of the laboratory. An X-ray machine of 680,000 volts capacity has recently been installed to handle large work. X-ray negatives 14 by 17 inches are used on all machines.

In one of the large ship-building plants, all castings subjected to heavy stresses, steam pressure, etc., are examined with the X-ray equipment shown in Fig. 32, in order to detect internal blow-holes or other flaws that are not visible. This X-ray equipment is also employed from time to time on steel fabricated structures to check the welds. It has a

rating of 200 kilovolt-amperes, and is applied for the penetration of metal to a depth of about 2 inches. The X-ray equipment is installed in a room about 15 by 25 feet, which is completely insulated with sheet lead.

Checking Thickness of Cylinder Walls with Magnetic Gage.—Fig. 33 shows how automobile cylinder walls are checked for thickness by means of a magnetic gage after rough-boring. This instrument consists of a cylindrical shell that contains a magnet and an energizing coil. Two pole pieces which extend slightly from the shell near the ends are ground to conform to the cylinder bore. The indicating meter at the top of the device, in conjunction with the

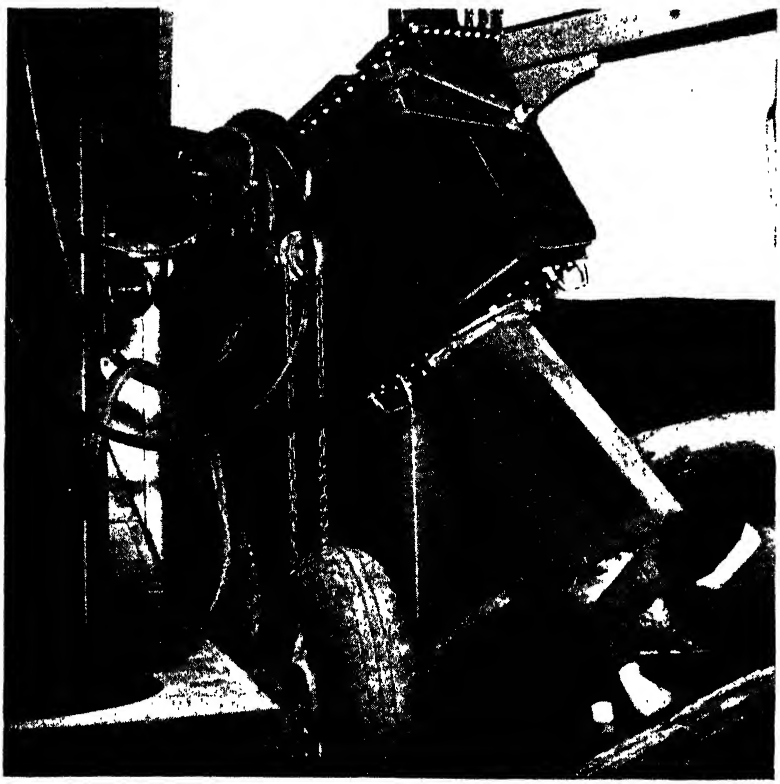

Fig. 32. Castings Subjected to Severe Stresses are Carefully Examined by X-ray Equipment for Hidden Flaws

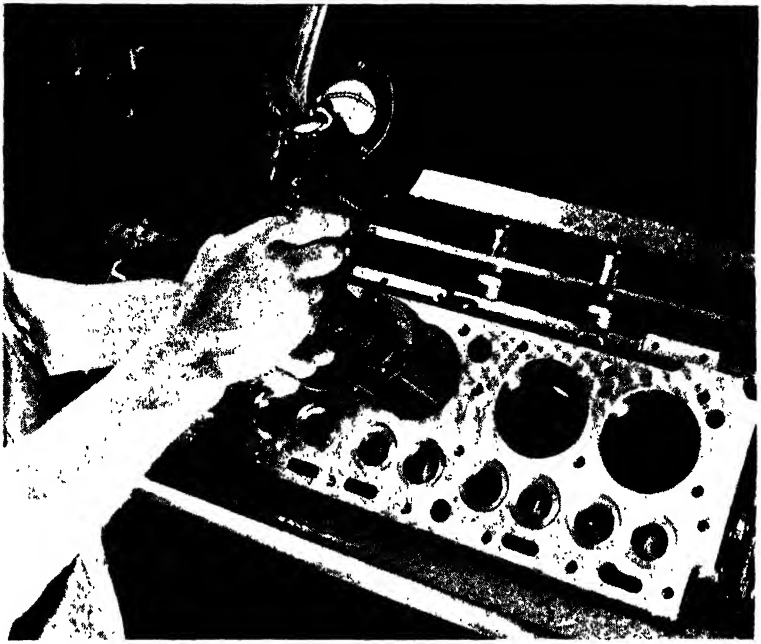

Fig. 33. Magnetic Gage Employed for Determining the Thickness of Automobile Engine Cylinder Walls

selector switch seen in front of the man's hand, enables the inspector to take thickness readings of the cylinder wall with either pole piece. The zero reading of the instrument is checked from time to time by applying the instrument to a master. Variations in thickness are indicated on the scale of the meter, each graduation being equivalent to a difference of 1/64 inch. The wall thickness of cylinders must not vary more than 1/32 inch. The use of this gage is facilitated by suspending it from a balancer located above the conveyor line.

Checking Concentricity of Bore and Squareness of Face.—The alignment of the bore in the bell housing of cylinder blocks with respect to the crankshaft bearings is checked in a fixture that is provided with two dial gages on a handwheel at the front of the fixture, as shown in Fig. 34. When the block comes to this fixture along the conveyor line, it

is slid on an elevating device. The cylinder block is then lowered on hardened and ground locating pads. An air-operated plug at the rear of the fixture next moves forward to enter the rear crankshaft bearing. At the same time this plug pushes the front crankshaft bearing on a stationary arbor at the front end of the fixture. When the handwheel is then revolved, a contact pin that rides against the finished face of the bell housing gives a reading of the squareness of this face with the center line of the crankshaft bearings. A second contact pin that rides around the counterbore of the bell housing actuates the needle of the other dial indicator and thus discloses any out-of-roundness

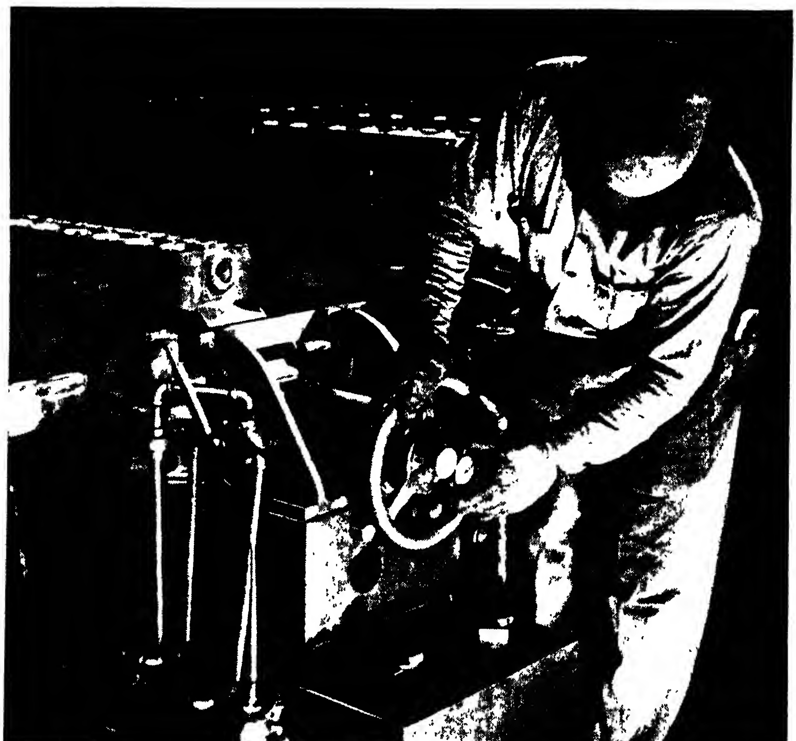

Fig. 34. Cylinder Gaging Equipment for Determining the Concentricity of the Bell Housing Counterbore and the Squareness of the Bell Housing Face

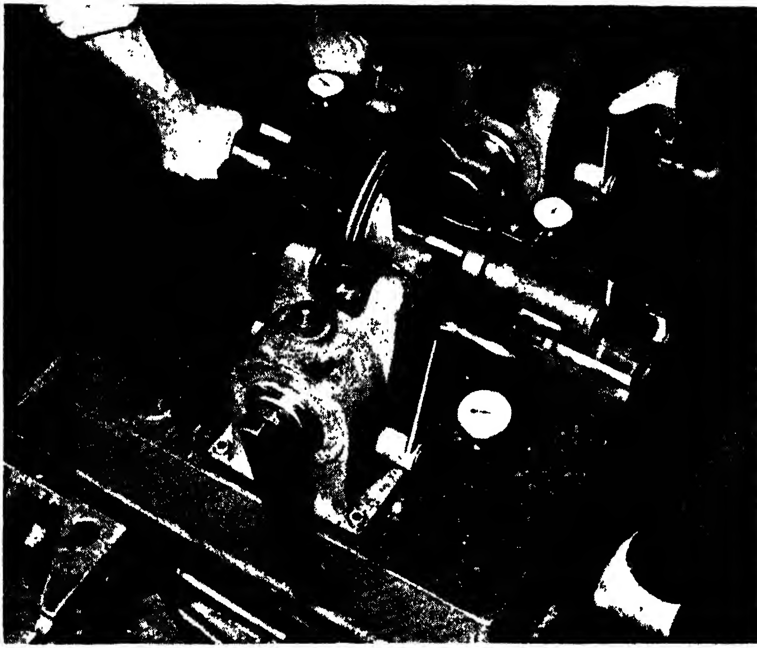

Fig. 35. Inspection Fixture which Facilitates Checking Various Elements of Differential Carriers at the Rate of 100 Carriers an Hour

of the counterbore. The bell housing face must be square with the crankshaft bearings within 0.003 inch and the counterbore must be concentric within 0.0025 inch. About 100 cylinder blocks are inspected hourly with this equipment.

Checking Various Dimensions of Differential Carriers.—Important dimensions of differential carriers are checked in the gaging fixture shown in Fig. 35. Before the carrier is placed in this fixture, the different bores are checked for diameter and concentricity by means of indicator gages, limits of plus or minus 0.0005 inch being specified for the diameter and concentricity. The cross bores of the differential carriers are marked according to these readings so as to enable selective assembly of the differential.

After the checking of the bores, one end of a long ex-

panding arbor is inserted into the drive-pinion bore. Then the carrier is placed in the fixture, as shown, with the expanding arbor supported in two V-blocks. Arbors that are permanently mounted in the fixture are next advanced into the cross bores of the differential carrier by turning crank handles. With the differential carrier thus located from the cross bores, the indicator at the back of the fixture, which registers against a bearing on the expanding arbor, can be used to obtain a reading of the squareness of the drive-pinion bore in relation to the cross bores. The bores must be square within 0.002 inch even though the reading is taken at a distance of 12 inches from the center line of the cross bores.

The dial indicator at the left on the front of the fixture is connected to a plug that registers against the under side of the expanding arbor and thus gives a reading of the up or down tilt of this arbor in relation to the cross bores. The center line of the arbor at this point must coincide with the center of the cross bores within 0.001 inch upward or 0.002 inch downward. The plug is raised into contact against the arbor for this reading when the right-hand arbor is entered into the corresponding cross bore and the plug is lowered when the arbor is withdrawn, so as to guard against damage to the plug when the expanding arbor is placed in the V-blocks.

The dial indicator at the right on the front of the fixture is actuated by a finger that registers against a ground shoulder on the expanding arbor, and thus provides an accuracy reading of the distance from the center line of the cross bores to the finished flange face of the differential carrier. This dimension is held to size within plus or minus 0.005 inch and the exact size is stamped on the work for selective assembly. Three men inspect 100 carriers an hour. Masters are placed in the fixture every half hour to check the zero readings of the dial indicators and thus insure inspection accuracy.

Fixture for Inspection of Flywheels.—The special gaging fixture illustrated in Fig. 36 was devised to facilitate the inspection of automobile engine flywheels for run-out or

trueness of the sides and for concentricity of the gear teeth. The sides are checked in the manner shown, by the operator observing the movements of the indicator needle on a dial gage as the flywheel is rotated in contact with the dial-gage spindle. The concentricity of the gear teeth is verified by observing the dial indicator on the left-hand end of the fixture, which, through the use of a pinion as an intermediary, shows up variations in the gear diameter.

Magnaflux Inspection.—Steering knuckles for a certain automobile must pass a Magnaflux inspection to detect flaws that would not otherwise be visible to the eye. The bench at which this operation is performed is shown in Fig. 37. The operator first places the rough-turned steering knuckle between two magnetic poles, as shown, and applies an electric current of 2200 amperes to magnetize the

Fig. 36. Inspecting Flywheels for Concentricity of the Gear Teeth and Run-out of the Sides. Two Indicator Gages Insure Accurate Readings

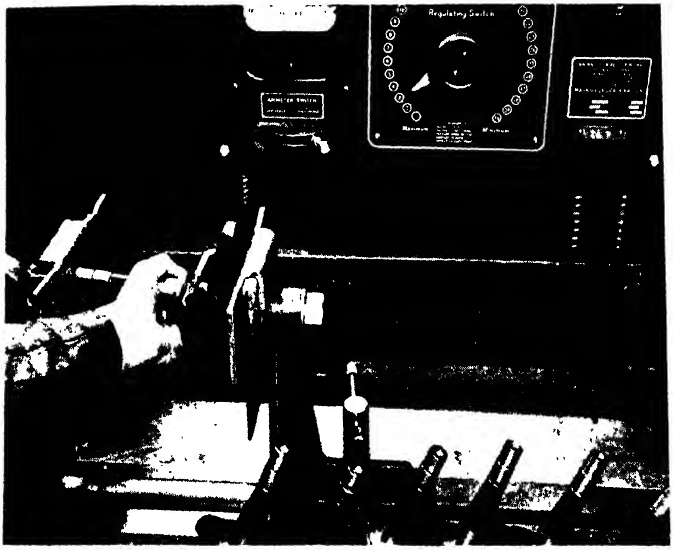

Fig. 37. Steering Knuckles Inspected by Magnaflux Process

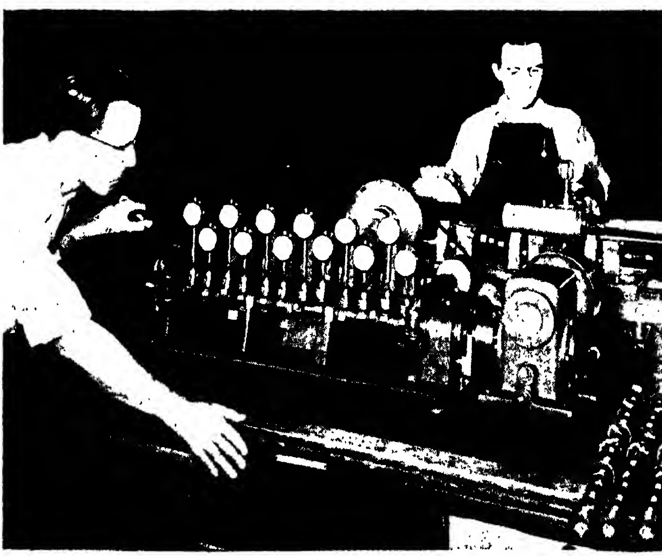

Fig. 38. Fixture for Checking Camshafts

part. Next, the steering knuckle is immersed in a Magnaflux bath which contains fine particles of iron in suspension. Any flaws at or near the surfaces of the steering knuckle are then clearly indicated through lines formed by the iron particles. The iron particles are released after the inspection by passing the steering knuckle through a simple demagnetizing fixture. A certain percentage of pistons is inspected in a similar manner. Magnaflux equipment has also been installed for the inspection of brake-drums. Automatic equipment performs this inspection at a fast rate.

Fig. 38 shows an inspection fixture designed for simultaneously checking the run-out of the base circle of all twelve cams on truck-engine camshafts. While the cam-

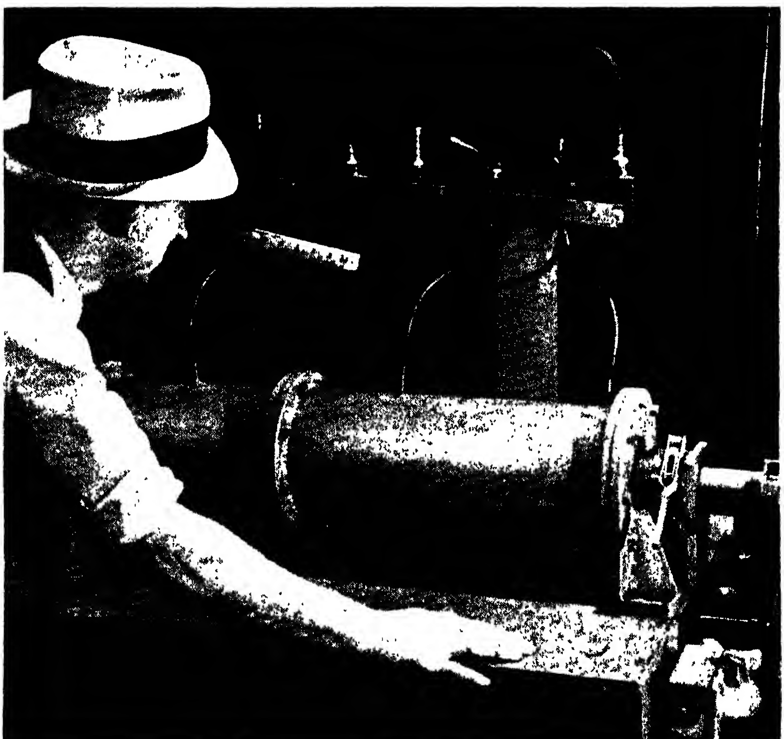

Fig. 39. Special Equipment Devised to Check the Amount of Air that can be Drawn Through the Ventilator Inlet and Oil Filler

shaft is slowly revolved, dial indicators graduated to 0.001 inch show the amount of run-out.

Equipment for Checking Air Flow.—Ingenious equipment used to determine the amount of air that can be drawn through the combination ventilator inlet and oil filler that is provided on certain automobile engines, is illustrated in Fig. 39. The pipe end of the part is inserted into the right-hand end of the inspection unit, as shown, and clamped air-tight by compressing a rubber bushing around the pipe through the operation of the small lever. Then a motor-driven fan at the left-hand end of the long cylinder is operated to draw air into the cylinder through the ventilator inlet. There is a vacuum inside the cylinder and therefore the amount of incoming air can be determined by means of the mercury gages at the rear of the bench. The right-hand gage is set to the predetermined air volume requirement and the inspector merely observes the left-hand scale on which the limits are clearly marked. It must be possible to pass from 2.5 to 4.5 cubic feet of air through the element per minute under 1 inch of water.

Checking Dimensional Accuracy of Bushings While under Working Pressure.—Steel-backed bushings for crankshaft bearings, and other types of split bushings, are checked in one plant for dimensional accuracy while under a pressure corresponding to that which will be applied when the bushings are installed in an automobile. This inspection is performed in machines of the type illustrated in Fig. 40, which comprises an arbor press equipped with a hydraulic cylinder for applying pressure to the ram. The bushing half to be inspected is placed beneath a half-round block attached to the ram and then the desired pressure is applied through the hydraulic cylinder. For example, in checking the steel-backed bushings for rear main bearings a pressure of 1620 pounds is applied and in the inspection of connecting-rod bushings, 860 pounds.

The pressure can be read from the upper gage seen in the illustration. However, it is not necessary for the inspector to refer constantly to this gage, because the press

is so arranged that a red electric light goes on if the pressure is correct. This feature has been found to greatly expedite the inspection. When the pressure is being applied, the dimensional accuracy of the split bushing is determined by reference to the lower gage on the arbor press, which gives a reading of the vertical position of the half-round block on the bushing being inspected.

Steel-backed bushings for main bearings are held to the specified size within plus or minus 0.00025 inch. They are inspected at the rate of 600 an hour. Split bushings for the small end of connecting-rods are allowed a tolerance of 0.002 inch and are checked at the rate of 1300 bushings

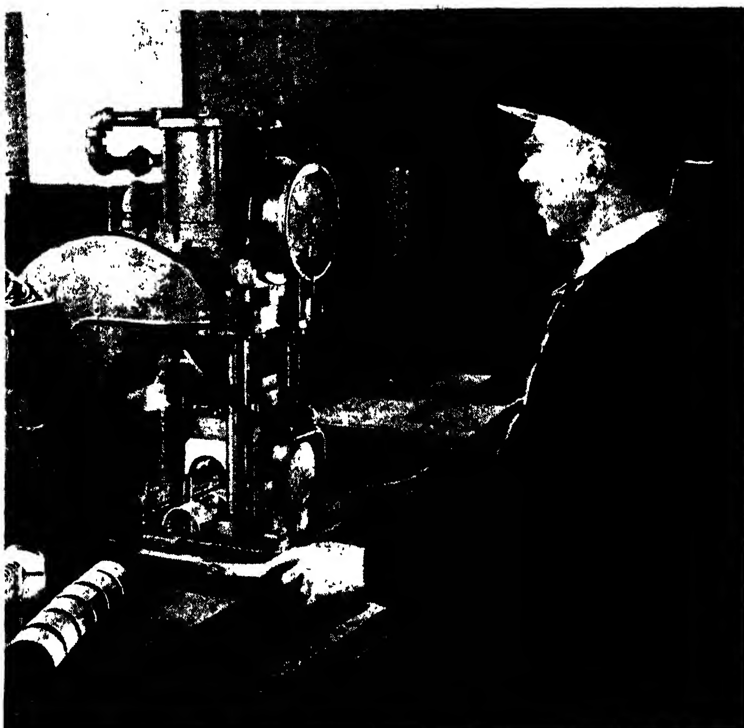

Fig. 40. Arbor Press Arranged for Checking the Radius of Steel-backed Crankshaft Bushings Under a Pressure Corresponding to that Imposed in Service

hourly. Master blocks are provided for setting the tolerance indicator to suit the part to be inspected.

Checking Dynamic or Running Balance. — In a prominent automobile plant, crankshafts, flywheels, and clutches are balanced individually within 1/2 ounce-inch, but they are again balanced after these three parts have been as-

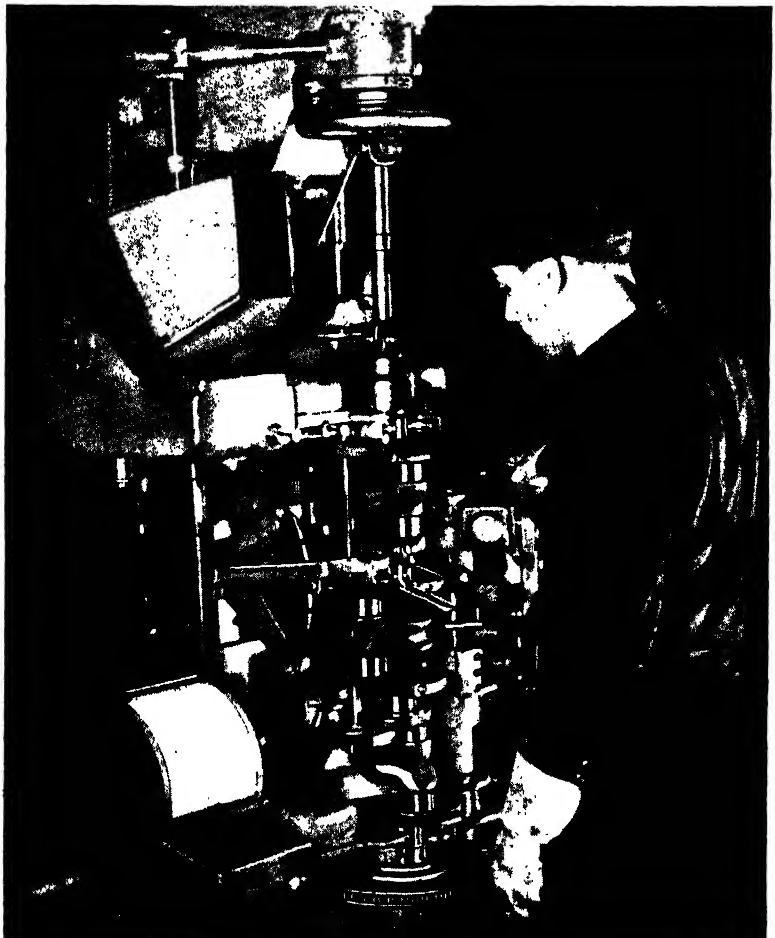

Fig. 41. Crankshafts, Flywheels, and Clutches are Balanced Individually and Then Again Balanced after These Three Parts have been Assembled

sembled and the entire assembly must be in balance within 1/2 ounce-inch. This precaution is taken because if the three parts of any unit were assembled with the heavy sides all in the same plane, the unbalance of the complete assembly could be as great as 1 1/2 ounce-inches.

Checking of the assembly is performed on the balancing machine in Fig. 41. The unit is run at 500 revolutions per minute. As the unit revolves, any vibrations of the crankshaft are reflected by a mirror and corresponding readings are obtained from charts at the top and bottom of the machine on the left-hand side. One chart gives readings for the lower end of the crankshaft and the other chart for the upper end. The vibration readings are greatly magnified on the charts, which show the amount of stock that must be removed from the unit in order to obtain balance. Graduations on a collar mounted on the machine spindle indicate the angular plane of the assembly in which unbalance exists. Corrections for unbalance are made by drilling the flywheel. A drilling head is provided on the right-hand side of the machine for this purpose.

Flywheels, clutch plates, fans, and spring housings for tanks are balanced both statically and dynamically in one plant on the electric-spark testing machine shown in Fig. 42. These parts must be in balance within 0.1 ounce-inch. Corrections are made by filing off stock. In balancing fans as shown, the fan is mounted on the end of a long arbor, so as to magnify any unbalance. The fan is an aluminum casting 36 inches maximum diameter.

All crankshafts for a certain airplane engine are checked for balance in the machine illustrated in Fig. 43, and the necessary corrections are made by drilling. Before a crankshaft can pass the inspectors, it must be in balance within 1 ounce-inch, as indicated by the machine, this being equivalent to 1/200 pound at the radius of the crankpin. Balance is checked in both ends of the work by merely operating electrical switches. Any unbalance in the crankshaft assembly causes the rests on which the assembly is supported to vibrate and produce changes in the resistance

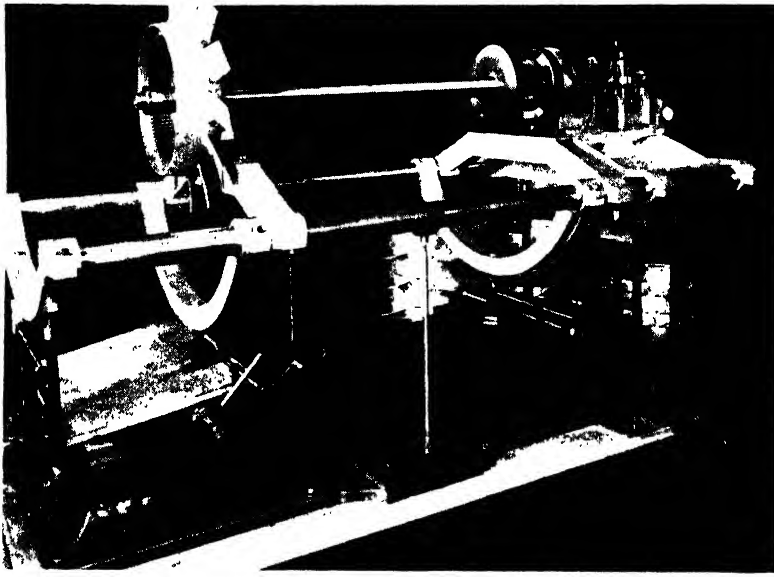

Fig. 42. Flywheels, Clutch Plates, Fans, and Spring Housings are Checked for Balance with this Equipment

Fig. 43. Machine Used in Balancing Crankshaft Assemblies within 1 Ounce-inch, for Airplane Engines

of electrical circuits. Corresponding readings on the panel board show the location and amount of unbalance.

Dynamic Balancing Machine for Rotors.—A machine developed for accurately measuring the unbalance that causes vibration of rotating parts such as rotors is shown in Fig. 44. The equipment operates briefly as follows: A rotor is mounted on flexible supports. This rotor is driven by a small motor at a constant speed. Voltages proportional to the vibrations of the two pedestals supporting the rotor ends are obtained by the device. These voltages are combined to give two voltages, one proportional to the unbalance at one end of the rotor and one to the unbalance at the other end. The amount of each voltage is metered, and the phase angles of these voltages with respect to the rotor position are also measured by the device, in order to locate the unbalance.

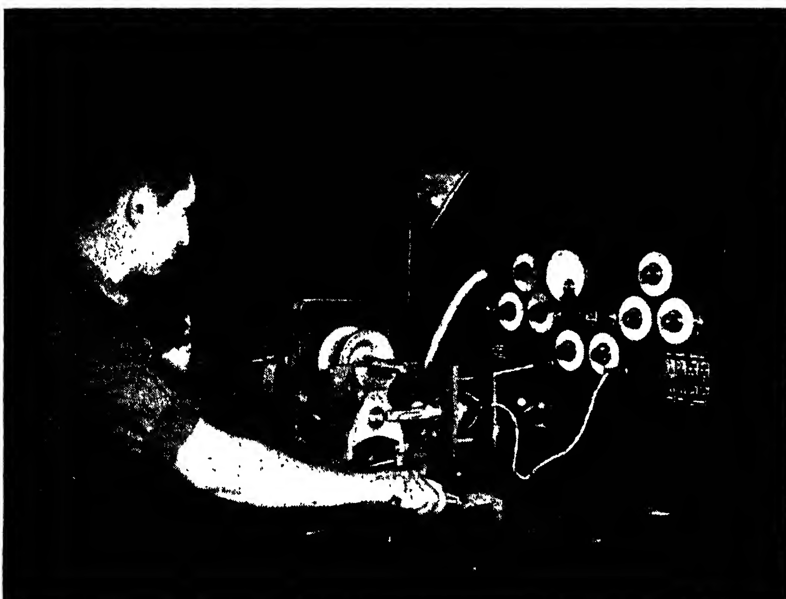

Fig. 44. Dynamic Balancing Machine Devised to Measure the Unbalance of Rotors Quickly and Accurately, Reducing the Once Complicated Problem of Balancing, with its Involved Calculations, to a Simple Reading of Meters

The two voltages created by the unbalance in each rotor are put into a circuit which acts as a calculating machine, giving answers proportional to the unbalance. The calculating device gives the solution for two simultaneous vector equations. The phase angle of the unbalance is obtained by having each of these voltages trip a stroboscopic lamp, which illuminates the rotor and shows, opposite a pointer, the position of the unbalance in question.

In its various forms, the balancer is as applicable to a rotor for a vacuum cleaner as to one for the largest turbines. Rotors have been balanced at speeds as high as 10,000 R.P.M. The machine is accurate far beyond commercial requirements. It will indicate 0.001 ounce-inch unbalance at one correction plane on a rotor 2 inches in diameter and 2 inches long.

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